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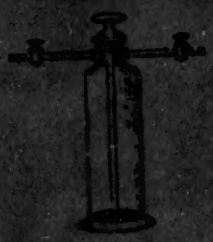

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PHYTOPATHOLOGY

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# WOUND-CORK FORMATION IN THE POTATO IN RELATION TO SEED-PIECE DECAY

M. Shapovalov and H. A. Edson

With Three Figures in the Text

The ability of the potato tuber to form rapidly a new cork over wounded surfaces has constituted a subject of many and varied investigations, particularly on the part of European scientists. Some of the studies were conducted on a broader comparative basis embracing similar cell activities of other plants. This work, though it may not be exhaustively complete, throws a considerable light on different phases of the healing processes.

Berchtold (3), as early as 1842, briefly recorded this phenomenon in his manifold monograph on the potato. He stated also that, according to his observations, "this healing power of nature" wanes with the advance of germination, its place being taken by a deep drying of the wounded surface.

Later Hugo de Vries (14) reaffirmed the above assertion and added certain new data. In his experiments some tubers were kept in the laboratory uncovered, from the time of harvesting until the next summer, and became badly sprouted and shriveled. On cutting, such material yielded no cork formation, even when sections were protected from drying. Only in extremely isolated cases were cross walls found. On the contrary, the material subjected to experimentation during the winter rapidly produced new cork which was of the same essential character as the old epidermis. Considerably wilted thin sections gave equally good results, provided they had not dried too much. He found that free contact with air accelerates the process of cork formation, while preserving or increasing the amount of moisture prolongs it. When tubers were stabbed with needles which were left undisturbed in their position for several weeks, subsequent cross sectioning revealed the formation of new cork in beautiful rings concentric with a layer of dead cells immediately lining the tunnel. Leaving the

needles in the holes, thus excluding the air and preventing evaporation, retarded the process, but did not prevent it. The author, therefore concluded that healing is exclusively a response to the irritation caused by wounding, but the exact manner of its accomplishment remained to be determined through further investigations.

Bretfeld (4) noted disappearance of the starch in cells destined to divide. He also ascertained that covering the wound by an artificially provided protective layer would not suspend periderm production. Cut surfaces of the tubers were severely scorched with red-hot iron sheets and examined two weeks later. A well developed new periderm was invariably present under the layers of burnt and dried cells. In this author's opinion neither the position of the wound surface nor the kind of wounding or destruction, whether from the outside or from the inside, has any effect on corking. Moisture, on the other hand, is very essential and the capacity of cells for division is determined by the relative water content. Large cells, rich in water content, in general all parenchymatous tissues, are considered to possess such ability. On the contrary, those cells which have already passed through a process of thickening are said to lack it.

The relation of external factors to periderm building in the potato was elaborately studied by Kny (6). Moderate atmospheric humidity appeared favorable to the process. Tubers held at a temperature of 6° to 7° C. for twenty-three days before wounding exhibited a somewhat greater activity than those kept during the same period at 18° to 21°C. Direct vs. diffused light; upward vs. downward, and horizontal vs. vertical positions of the cut surfaces proved to be immaterial. Mercurial vapor pressure at ordinary room temperature was without effect. Iodine fumes in small quantity, and for a few days only, did not hinder the building of the wound epidermis, but caused a disturbance of the upper layers of the wound surface. Oxygen was found to be necessary for the corking of the membrane, but not for the origination of the cell division. When the conditions were right, the cross walls began to form after the lapse of two days.

Conditions similar to those described by de Vries in tubers artificially pricked with needles were observed by Prunet (12) in potatoes penetrated by grass roots (*Cynodon dactylon* Pers., *Triticum repens* L.). First, there was a layer of dead brown cells immediately adjacent to the channel; next to this were several layers of a very delicate cork which the author terms the "suberized layer" and, finally, the undisturbed normal tissues of the potato. The "suberized layer" becomes gradually attenuated toward the tip of the penetrating root, disappearing altogether shortly before the termination of the dead layer.

Kny (7) once more took up the problem of wall formation in wounded plants and studied particularly the effect of tension and pressure on the

orientation of the new walls. Normally the so-called "initial cells" exert pressure upon each other in the direction parallel to the wound surface, while the growth stretch is perpendicular to it. The cross walls, therefore, are formed in the direction parallel to the wounded surface. Kny by means of special devices involving the application of weights ranging from 872 to 1424 grams to the slices of potatoes several millimeters thick diverted both the pressure and the tension in the direction just opposite to their natural course. Consequently, it is stated, the new cross walls formed were perpendicular, instead of parallel, to the wound surface. The conclusion is that pressure and tension determine the direction of wall deposition. Certain other experiments were performed to show that the position of the source of oxygen inflow has no significance in this matter.

Massart (9), however, was somewhat reluctant in accepting Kny's views on the importance of pressure and tension. He points out that in the latter's experiments with comparatively thin slices of potatoes fissures could appear readily under the weights employed. In this case, of course, cell walls would be formed parallel to the cracks, i.e., perpendicular to the old wound surface. In his opinion the segmentation is a response to the irritation caused by wounding and has an analogy with such reactions as heliotropic and chemotactic response. When the cells attain a sufficient length, they divide and the cell walls are perpendicular to the main axis of the cell and, consequently, parallel to the lesion. Disappearance of the starch and thinning of the thick walls during this process is noted. Exposure to the air is considered necessary for the impregnation of the new walls with suberin.

To the data thus far accumulated by these previous studies Nemec (10) added, at the end of last century, certain interesting cytological studies revealing the process of the nuclear division accompanying that of the cell division in cut or otherwise wounded potatoes. The fibrils of the achromatic figure are monaxial in all ordinary cases and run parallel to the axis of the division. However, when a cell is located in the corner of cell complexes and is, therefore, exposed on more than one side, the cell division either does not occur at all, or it appears in different directions which cannot be determined beforehand. In this latter case the nucleus becomes surrounded with a "periplast" in which the fibrils are neither monaxial nor parallel, but emanate radially from all sides of the nucleus.

Early in the present century Olufsen (11) published his extensive studies of the wound-periderm formation in the potato which in part were conducted along the lines selected by Kny for his first work. According to this writer, a mere exposure of the cell, made in a variety of ways, leads to cicatrization. The disappearance of starch in the initial cells generally goes hand in hand with the formation of the periderm walls. Starch in the

cells lying between the initial cells and the wound surface was set free presumably for the same purpose, before the passage was closed by the corking over process. Unripe and undeveloped tubers were found to react quicker to wound irritation, while dead and thickened portions of the tissue were unable to transmit the stimulus. In general, the larger the cell complex in relation to the lesion, the more favorably the building of the periderm proceeds. The topography of the periderm surface is not flat, but rises closer to the wound surface in the vascular ring and sinks in the pith as well as in the cork. Lenticels may heal over normally only under very dry conditions and upon infliction of a wound. Moderate moisture was found again to be the most essential requirement for periderm formation; an excess of it plays a hindering rôle and causes cell proliferation. Light exerts no perceptible influence on the healing process and oxygen, as found by Kny, is important only for the suberization. Temperature influences healing only as it does other phenomena of growth. Poisonous solutions did not prevent cicatrization. Quick-silver vapor had no effect. Iodine vapor was slightly harmful. Ethyl ether vapor had a certain checking effect. The newly formed wound cork, according to Olufsen, constitutes a powerful protection against the invasion of micro-organisms, better even than the older normal skin layer. An observation is recorded on corner cells where two wound planes united. In this case the cross walls were built in different directions, showing a response to irritation from two sides.

Appel (1) was the first to investigate the problem from the viewpoint of a pathologist, namely in its relation to plant diseases. In his experiments with potatoes kept in a moist chamber at 20°C., the suberization of the cut surface had made such progress twelve hours after cutting, that a virulent culture of *Bacillus phytophthorus* was unable to penetrate the tissue, although the new periderm was not yet formed. The latter appeared within forty-eight to sixty hours and under favorable conditions the whole process was completed in two additional days. If, on the other hand, the cut potatoes were exposed to drying in a warm room or in the sun, the drying proceeded too rapidly to permit periderm formation. He found, however, that the process may take a normal course again when such material is placed in moist soil. Although micro-organisms may gain entrance into the softened dry layer, new cork formed below it will constitute a sufficient protection against their further advance. Appel does not accept Olufsen's idea of a centripetal movement of starch, but he admits that cells lying below the initial cells furnish material for periderm formation. When the formation of the walls is completed, the inner tissue becomes closed to further effect of irritation and the entire process reaches its end. The conclusions of Kny and Olufsen with regard to the importance of oxygen for the corking of the tissues is supported by this writer.

Incidently Appel (2) spoke on the phenomenon of wound-cork formation in the potato in his lecture on "Disease Resistance in Plants" delivered in the United States in 1914. He mentions an interesting fact that "Some varieties begin cork formation within six hours after the wound is inflicted, while in other varieties it is not begun for forty-eight hours or more. From this it is clear that the former may withstand infection better than the latter."

Recently Hawkins and Harvey (5) in the course of their work with *Pythium debaryanum* found that "None of the wounded potatoes, inoculated three hours or more after they had been placed in the incubator, were rotting." The temperature employed was 30°C. They further state: "It is evident that the protective covering is formed very quickly under the conditions of the experiment. Whether this is due to a suberization of the tissue was not determined." In the light of previous investigations showing that with lack of moisture, in a dry and warm place, the desiccation of the cut surfaces is more rapid than the formation of the new cork, it appears probable that in the Hawkins and Harvey experiments a mere drying of the surface tissue offered a sufficient protection against the fungus penetration.

In closing the review of the literature on the subject it seems worth while to mention here that a special method for staining suberized tissues was offered by Tison (13). Essentially it consists in using ammoniacal solutions of one of the following stains: gentian violet, dahlia, Mangin's acid green, methyl green and Paris violet. Ammoniacal fuchsin is said to give unsatisfactory results. The author claims that his is a rapid method, gives an intensive stain, permits differentiation between the suberized and the lignified tissues and provides for a double stain which is very distinctive. Sections prepared by the above method and mounted in neutral glycerin can be preserved for a long time.

In the light of certain experiments enumerated here it may seem quite evident that the wound periderm in potatoes as well as in other plants constitutes a powerful protection against parasitic invasion and, indeed, is designed by nature for such a purpose. Nevertheless it is an interesting fact, which may be observed frequently in the field, that the decay of the cut seed tubers begins, as the rule, on the wounded surface and not on the old unbroken epidermis. This fact has been recently recorded by McMillan in his paper on Fusarium blight (8). He particularly emphasizes the fact that the decay originates at the center of the seed piece and thence spreads gradually and radially toward the rind. He states: "The interior loose parenchyma at the center of the tuber, farthest from the active tissue of the vascular region, is the weakest and the least protected." And further: "The region adjacent to the active tissue is the last to decay be-

cause it is more resistant and because the decay begins in the loose parenchyma and advances toward the germinating point or place of attachment of the shoot." The relation of this interesting and important phenomenon to the actual course of callus formation has not been studied.

Among various phases and details of the problem which still remain unsolved by the previous investigations the following points attracted the attention of the writers:

1. Whether a mere sprouting of the tubers is sufficient to prevent the formation of the wound cork;

2. Whether dusting with sulphur, which is a common practice among many potato growers, has any effect on it;

3. Whether the entrance of the decay at the center of the seed piece has any bearing on some peculiarities of the corking process.

Experiments designated for the solution of these questions were carried on with three standard American varieties; Irish Cobbler, Green Mountain and Bliss Triumph. Within the limits of our observations no difference in the response of these varieties was noted. At first, only two types of tubers were used: those unsprouted or only barely sprouted, and those which had sprouted well but comparatively recently, after being removed from good storage conditions. Each tuber was quartered longitudinally with a sharp knife. The two types of material were each divided into two parts, one of which was heavily dusted with sulphur, and the other left untreated. Both treated and untreated parts were in turn divided in three lots subjected to different handling. The first lot was placed in a glass moist chamber which was then held in a dark cabinet of a laboratory room; the second was kept in an open dish on a laboratory table exposed to light, and the third lot was immediately planted in soil, in pots placed on a greenhouse bed and later watered as usual. This experiment was repeated three times: in February, in June, and in November. A detailed microscopic examination was made on the fourth and ninth days with some supplementary observations on other days. Thin free-hand sections of the fresh material answered the purpose in a quite satisfactory way and permitted preparation of semi-diagrammatic camera lucida drawings illustrating the conditions.

The formation of the new walls was not noted until after two days. Beginning with the third day it was quite apparent and thereafter followed practically identical courses with sprouted as well as unsprouted tubers, both treated with sulphur and untreated. Drawings *A–D*, *I–L*, and *Q–T* represent sulphured lots and the remainder, unsulphured ones. Other conditions being equal, no distinguishable effect of this treatment was manifested.

A comparison between the first four drawings and the last four drawings

in each text figure gives a fair idea of the conditions on the fourth day and the ninth day respectively.

The process of the wound cork formation in the sections kept in a moist chamber was quite similar to that of the specimens buried in the soil (figs. 2 and 3). It was characterized by a very thin layer of dark brown suberized cells and an abundance of the newly formed cross walls. The former is even somewhat less pronounced in the specimens kept in the soil, where it is almost limited to one row of cells adjoining the wound surface and remains practically unaffected by the time factor.

On the contrary, the material exposed to the light and drying presents an entirely different picture (fig. 1). Already after three days the layer of suberized walls is much thicker here than under the other conditions. As time goes on the browned cells become shriveled and depressed, and new underlying layers are rapidly added to this mass while the whole process tends to suppress the further development of the new periderm.

Regardless of the treatment of the cut tubers a marked contrast both with regard to the regularity and the profusion of the cell division was manifest between the central and the peripheral sections. While occasionally the periderm formation in the center may be fully equal to that at the periphery, on the whole it is much less advanced. This condition is represented by alternate drawings in figures 1–3 (*A–C* vs. *B–D; E–G* vs. *F–H*, etc.). It follows, therefore, that the central portions are less protected against the invasion of parasitic fungi and bacteria, at least, so far as the cork cover is concerned. The decay of the seed pieces in the field naturally sets in at the least resistant points. In the writers' own experiments some of the cut tubers became affected with a rot started approximately in the middle of the ridge formed by two wound planes of the piece.

In order to see more clearly whether or not greater abundance of moisture in the central portions of the cuts might account for the retardation of the periderm formation, some of the unsprouted longitudinal sections of the tubers were cut crosswise in the middle and one part was placed in an open dish and the other in a moist chamber. On the fourth day the exposed pieces showed a deep drying of the surface layers and an absence of new walls. The specimens in the moist chamber, on the other hand, were in a normal state of turgidity and the healing process was proceeding as usual. It was well advanced in the portion of the wound nearest the old epidermis, showing the starch-free area and the new walls in the elongated old parenchyma cells. At the summits formed by three wound surfaces, on the contrary, it was barely at its beginning. Only occasional new walls could be found and even the "starch-free" area was not clearly differentiated.

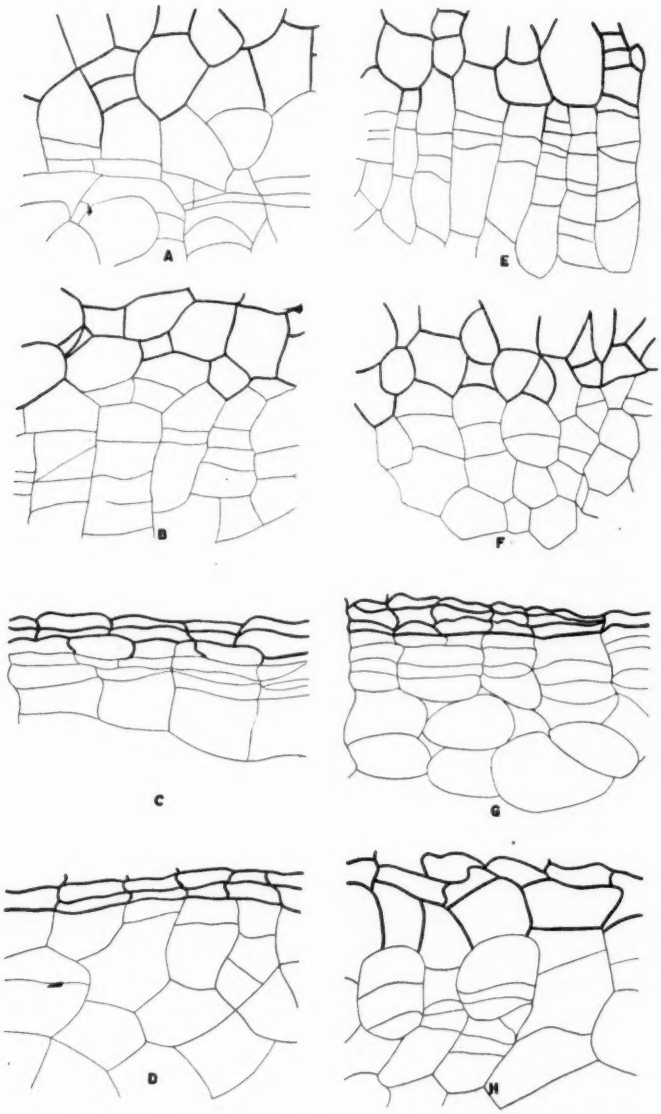


FIG. 1. CAMERA LUCIDA DRAWINGS SHOWING THE WOUND-CORK FORMATION IN THE TUBERS KEPT IN AN OPEN DISH EXPOSED TO LIGHT

*A, B, E, F,* on the fourth day; *C, D, G, H,* on the ninth day. *A–D,* treated with sulphur; *E–H,* untreated. *A, C, E, G,* from portions adjoining the old epidermis; *B, D, F, H,* from the center of the tubers.

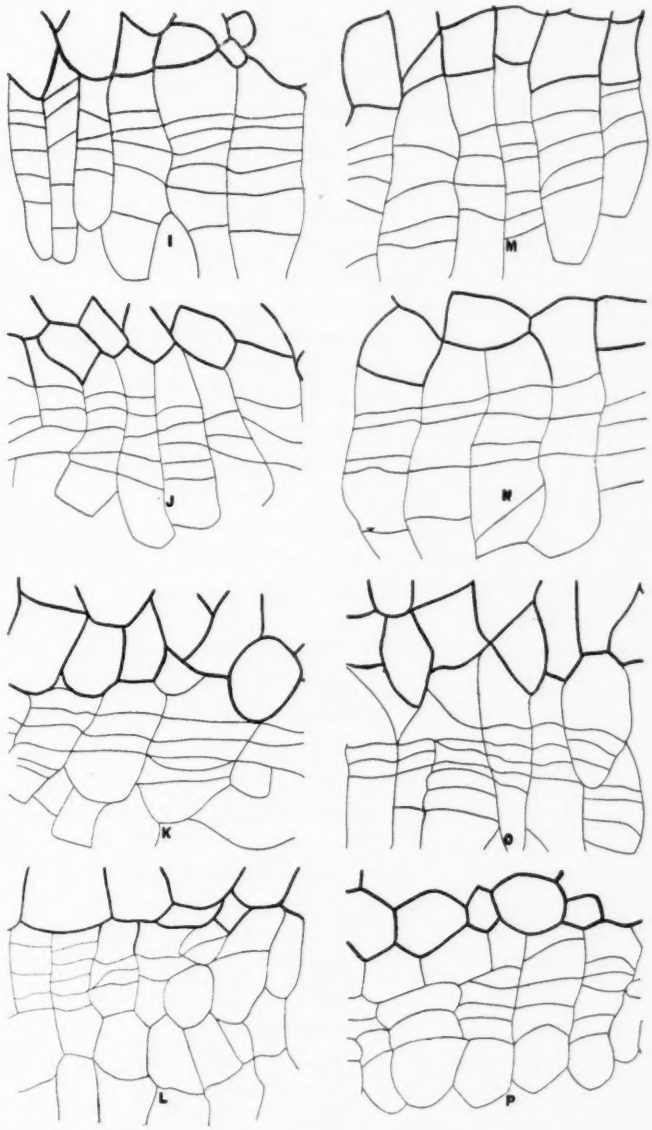


FIG. 2. CAMERA LUCIDA DRAWINGS SHOWING THE WOUND-CORK FORMATION IN THE TUBERS KEPT IN A GLASS MOIST-CHAMBER PLACED IN A DARK CABINET

*I, J, M, N*, on the fourth day; *K, L, O, P*, on the ninth day. *I–L*, treated with sulphur; *M–P*, untreated. *I, K, M, O*, from portions adjoining the old epidermis; *J, L, N, P*, from the center of the tuber.

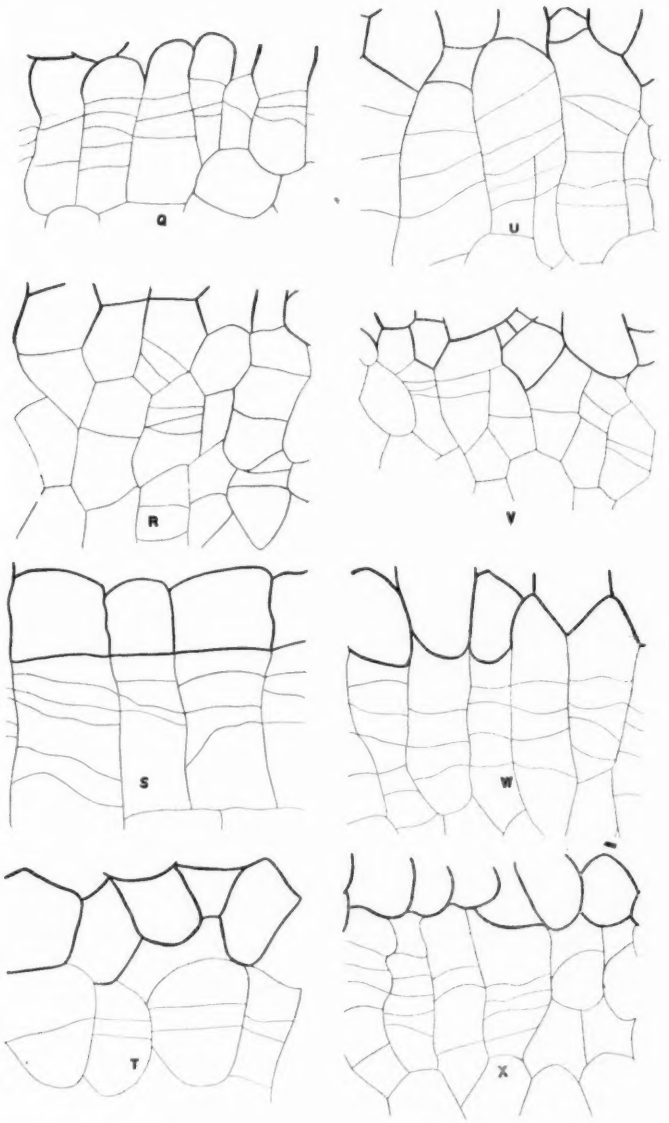


FIG. 3. CAMERA LUCIDA DRAWINGS SHOWING THE WOUND-CORK FORMATION IN THE TUBERS BURIED IN THE SOIL

*Q*, *R*, *U*, *V*, on the fourth day; *S*, *T*, *W*, *X*, on the ninth day. *Q*–*T*, treated with sulphur; *U*–*X*, untreated. *Q*, *S*, *U*, *W*, from portions adjoining the old epidermis; *R*, *T*, *V*, *X*, from the center of the tuber.

The positive results secured with the germinated tubers show that sprouting alone does not arrest the ability of the potato tubers to form a wound cork. As stated by de Vries, his observations were made upon the material not only sprouted but also badly shrunken through drying in a warm laboratory. In this case the effect of desiccation shown in the above experiments and brought forward by Appel and other workers, had probably played an important part. In order to compare the behavior of shrunken tubers with those merely sprouted, some suitable specimens were procured in April which had remained in a warm room at Washington since they were received from Maine the previous season. The material included two varieties, Bliss Triumph and Green Mountain, of which the latter were considerably more flabby than the former. The tubers were cut in four parts longitudinally and, except for the sulphur treatment, which had been of no significance, they were handled as in the earlier tests, i.e., one part was exposed to drying in the air, one was placed in a moist chamber, and one was buried in the soil. As a check, firm and unsprouted tubers were treated simultaneously in the same manner. Three days later all pieces kept in an uncovered container appeared to be considerably dried and shriveled. The wall formation in the control tubers, though present, was far from abundant; it was still more rare in the old Bliss Triumphs and quite absent in the badly shrunken Green Mountains. In a moist chamber the healing process was going on quite normally, duplicating with the checks the conditions illustrated by the drawings, somewhat approaching it with shriveled Bliss Triumphs, and still at hand, although distinctly slackened, with the extremely dried Green Mountains. If these latter were kept in the moist chamber for an additional week or longer and the wound or any part of it escaped parasitic invasion, the healing process developed further and reached a normal degree. In the soil (not sterilized) the Green Mountains for the most part contracted fungous and bacterial infection and decay set in promiscuously here and there over the entire wound surface. Occasionally small areas took up moisture and became firmer, but the formation of the new walls in these areas was not evident. In Bliss Triumph pieces there was less decay and more of the turgid areas, but neither new walls nor the usual starch-free layer could be seen. The behavior of the check pieces was normal. After the expiration of another three days almost the entire old Green Mountain material was so disorganized by the decay over its wound surfaces that there was no possibility of either new cork formation or examination. Only one quarter-tuber out of sixteen presented an exception. In this piece the rot was localized at the center while the edges along the border of the old cork were quite free from it and had a firm more or less normal appearance. Sections through these areas revealed starch-free layers, and a number of

lengthened parenchyma cells together with new cross partitions. Bliss Triumphs again were in better condition than the Green Mountains, fully 50 per cent of the wound surface being undisturbed by the decomposition, and the rot, as a rule, was confined to the centers. Sections through the comparatively healthy portions showed that the healing process here was well advanced, being practically equal to that in well preserved, normal tubers.

A modification of the above experiment emphasizes still more strongly the fact that moisture content and not germination is the determining factor in the healing process of the sprouted potato. The tubers of the two named varieties of the same origin were cut in the usual manner and then soaked in water for (a) over night and (b) three days. Both groups (a) and (b) after the time stated were removed from water, left to dry slightly at room temperature and then placed in moist chambers. The behavior of the different varieties was similar to that in the soil, i.e., Green Mountains, being in an advanced degree of desiccation and subsequent disintegration, became promptly and generally affected by molds and bacteria, while Bliss Triumphs which were less flabby and appeared to possess more vitality at the start showed more resistance to decay. Microscopic examination on the fourth day revealed no evidence of new walls in either lot of either variety. After the lapse of an additional three days the starch-free area became well pronounced and the newly formed cross walls could be seen here and there. This, however, applies mainly to the firmer tubers of the Bliss Triumph variety, since most of the Green Mountains were thoroughly decomposed by that time.

Just as the absorption of water by shriveled tubers regenerates their ability for wound-cork formation, so an artificial dehydration of firm, sound potatoes weakens this ability. This was shown by an experiment in which a number of freshly dug as well as old, well preserved tubers were kept in a vacuum desiccator over calcium chlorid. The new potatoes were all of the Irish Cobbler variety and the old ones were partly Irish Cobblers and partly Bliss Triumphs. A duplicate set of similar material was held in an ice box as check. In from four to six weeks the specimens in the desiccator became considerably shriveled, particularly those which were smaller in size and more or less wounded. Both the treated and the control specimens were then cut up and placed in a moist chamber as in the previous experiments. The result was that the most flabby tubers turned black and slimy within twenty-four to forty-eight hours with a rapid bacterial decomposition after that period. Tubers in a medium stage of dehydration did not turn black, although nearly 50 per cent of them were also affected by a decay. In the pieces remaining unaffected the periderm formation was present although much retarded, the new cross walls being

only occasional on the sixth day. On the contrary, the control specimens showed at this time several distinct layers of the new walls distributed quite generally and regularly under the cut surfaces. The above response to the wound irritation in different stages of desiccation was practically identical in the case of both the new and the old tubers.

On the basis of the results secured in the experiments described in this paper the answers to the three specific questions set above will be as follows:

1. Sprouting alone does not affect the ability of the potato tubers to form a new cork over the wound surfaces, but drying of the tissues which usually accompanies germination when potatoes are stored in a warm room for a long period, checks this ability.

2. Sulphur applied to cut seed pieces has neither beneficial nor detrimental effect on periderm formation.

3. The observed origin of decay at the central surface of the cut seed pieces in the soil correlates amply with the inferior healing proclivity of the central portion as compared with that of the more resistant peripheral areas.

The general susceptibility of badly shrunken tubers to attack by decay producing organisms in the soil is of outstanding practical significance. It emphasizes the importance of proper storage conditions for seed potatoes at a reasonably low temperature and suitable humidity to prevent excessive evaporation. The resistance of the seed piece to attacks diminishes in direct proportion to the water loss and a shriveled tuber is unable to initiate cell division until it has imbibed the necessary amount of moisture from the soil. Consequently, destructive activities of micro-organisms develop so rapidly that the formation of the protective layer under the infected lesions is often checked completely and the seed piece fails to grow entirely or produces only feeble undernourished shoots.

BUREAU OF PLANT INDUSTRY
WASHINGTON, D. C.

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# MARKET PATHOLOGY AND MARKET DISEASES OF VEGETABLES

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## I. THE FIELD OF MARKET PATHOLOGY

The coöperative war emergency work of the Bureau of Plant Industry and the Bureau of Markets has brought into sharp relief a phase of plant pathology which hitherto has been touched only casually by pathologists. This is the field of market pathology as contrasted with that of production, or field pathology. Production pathology deals with the diseases which affect the growing plant; market pathology with the diseases economically important in fruits and vegetables after the harvest, whether in the field, in the packing house, in transit, in storage, or in the markets. Since market pathology affects directly many business interests it presents economic and legal problems quite unlike those of production pathology.

Until of late American pathologists have devoted their attention almost exclusively to the problems of production as they have had little occasion or opportunity to study those of marketing. The nearest approach has been the investigation of storage diseases. A recent study of market conditions has revealed that the pathological problems involved in the marketing of the products of the field and orchard are fully as important from an economic point of view as those of crop production. These problems are especially pressing in America, where perishable products are transported over long distances, and such diseases therefore deserve serious attention by American pathologists. They also are important factors in foreign, especially overseas, trade and consequently are of international significance.

### *History*

The pomologists were pioneers in this field of study. Powell with his co-workers and associates (1) in the Bureau of Plant Industry was the first to point out the importance of decay as a factor in the marketing operation. He carried out a series of investigations designed to improve the technique of picking, handling, packing, shipping, and refrigerating California citrus fruit so as to prevent decay. Ramsey (2) investigated the effect of careful handling, precooling, and refrigeration in transit upon the shipping qualities of red raspberries.

Not until much later did pathologists give attention to this field of study. Stevens and his associates (3) have studied the relation of rots to the marketing of strawberries. Hawkins (4) worked out the relation of potato leak to handling methods; Meier (5) has worked on stem-end rot as a factor in the marketing of watermelons; and Rosenbaum (6) has studied the Florida tomato situation with reference to field and transit conditions.

F. L. Stevens (7) was the first pathologist to take up transportational diseases as a general theme. His attention had been called to this phase of pathology by the Illinois Central Railroad, which had come to him for expert advice on the subject. Coons and Nelson (8) later made a study of the condition in which fruits and vegetables arrived in the Illinois Central yards in Chicago and their well-illustrated publication based on these studies cites the important literature and stands as the first attempt to thoroughly cover this field. Shear (9) has recently pointed out the significance and possibilities of market pathology.

### *Present status*

With the inauguration of the Food Products Inspection Service of the Bureau of Markets in 1917, market pathology received its greatest impetus. Wm. A. Orton, Wm. M. Scott, and C. L. Shear saw the desirability and necessity of coöperative work between the Bureau of Markets Inspection Service and the pathologists of the Bureau of Plant Industry. This cooperative work not only provided the opportunity but also made it necessary for pathologists to survey conditions in all of the large markets of the country; to visit wholesale produce houses, to study conditions in cars in the terminal freight yards of the large cities, to visit the important shipping points and packing houses; and to correlate the conditions found at shipping and receiving points.

A plan has been devised which enables the Plant Disease Survey to incorporate into its reports all pertinent data gathered from the certificates executed by the inspectors in the markets. The attention of state and extension pathologists is also called to losses in shipments of vegetables originating at points within their respective jurisdictions.

### *Results of first year's work*

In this paper will be presented a summary of the results of the first year's study of the market pathology of truck crops. These results will be presented more completely in an illustrated handbook prepared primarily for the use of the inspection service but ultimately to be made avail-

able, it is hoped, to all interested persons including growers, shippers, buyers, distributors, and consumers.

For the present report no claim of completeness is made. On account of the small number of observers, the results necessarily have been obtained by scattered observations in many markets and by fairly continuous observations only in New York and Chicago. It is fully realized that the pathological aspects of no two years are exactly alike. For example, the losses in Florida citrus fruit due to blue mold rot and stem-end rot are very heavy at present (season of 1918–1919) often involving 50 per cent of a car, whereas last year's losses from these sources were practically negligible. While certain climatic extremes and transportational difficulties may have rendered the past year quite abnormal in many respects, it is believed that whatever work is done in the future will leave certain fundamental aspects of market pathology as noted, essentially unchanged.

One of the outstanding developments of this coöperative investigation is a surprising revelation of the enormous annual loss of fruits and vegetables due to disease during transit. Such losses are particularly lamentable because of the time and labor value concentrated in the harvested product enroute to market. The certificates sent in by the market inspectors covering the watermelon shipments from four states during the 1918 season indicate a minimum loss of $1,250,000 or an equivalent of 2500 cars. In one week as many as 2500 hampers of Louisiana head lettuce have been rejected as a total loss at the car door in Chicago. Heavy losses were also suffered by the grape industry of California during the past season. Hundreds of cars were almost total losses due to decay induced by Botrytis, Penicillium, and Aspergillus. In one case, a badly affected carload brought only $18 at auction on the Chicago market. It was found that in the shipments of Cuban pineapples 15 to 25 per cent losses due to Thielaviopsis rot are accepted as a matter of course. Consequently pineapples are customarily repacked in the car. Tomatoes shipped any distance at all are always carefully sorted by the carlot buyer, particular attention being paid to the elimination of immature and unsound specimens. Probably 15 per cent of all tomatoes shipped out of California, Cuba and Mexico into distant markets are discarded because of decay. Potatoes and cabbage in bulk shipments generally must be resorted. Green vegetables, especially lettuce and beans, usually must be sorted and reconditioned upon arrival in the markets.

Equally important is the revelation of the fact that up to the present the majority of those who deal with fruits and vegetables have accepted these losses stoically and as a matter of course. They have considered them "a part of the game," and refer to them as "excessive shrinkage." The business, or rather the industry as a whole, and ultimately the consumer, ab-

sorbs the loss. The resorting inaugurated by the carlot receiver continues with the wholesaler and retailer. This generally enables them to make a tempting display of fruits and vegetables, but also compels them to charge almost prohibitive prices for their wares. Naturally the price is so placed that the losses due to rots and the labor cost of the resorting and repacking are covered. Low prices to the producer, high transportation charges, and high prices to the consumer are the inevitable results.

### *Possibilities and prospects*

Therefore, from an economic point of view it is a hopeful omen for all concerned and augurs well for the future support of plant pathology, that the contacts established with these groups are bringing to them the realization that such losses are due mainly to plant diseases, many of which are controllable, and not to "inherent weakness." The propaganda and educational work which has been carried on for years among growers should be extended so as to reach the buyers, shippers, dealers, carriers, and consumers of fruits and vegetables. When the buyers and distributors once realize that their losses are mainly due to diseases, they will insist that a sound, disease-free product be delivered to them. This will lead to improvements in production methods such as the use of disease-free seed, seed disinfection, spraying, and field sanitation, since the financially successful grower must grow what he can sell. So long as he can sell inferior, unsound diseased products there is no incentive to produce high-grade, disease-free stock.

As a result of this realization on the part of the shipper, the railroads, and the trade, that their losses are largely due to plant diseases and hence are preventable to a certain extent, an urgent demand is being made by them that pathologists include in their field of interest, in addition to the disease factor in the production of crops, the pathology of these crops during harvesting, storing, shipping, and marketing.

Not only is this necessary in order ultimately to reduce the losses but the legal aspects of the situation call for much more definite knowledge regarding the source, time, and place of infection and the conditions favoring infection and spoilage of the products. Such questions are continually arising for settlement and adjudication. Accurate data and facts gained by experimentation are necessary to enable the courts and arbiters to make a more just apportionment than is made at present of the responsibility for such losses among the parties concerned, viz., the grower, the shipper, the carrier, and the consignee.

In addition to research directed towards prevention of these losses from the standpoint of conservation, it is evident that there is great need for

work along the lines of salvage. The enormous quantities of perishables rejected in railroad yards could by proper processes be made to yield valuable by-products.

Not only should the field of market pathology form a valuable adjunct to the facilities for plant disease survey work but the authentic data obtained relative to the losses due to certain diseases will supply to plant pathologists a type of information hitherto extremely difficult to secure. Such data should furnish to state pathologists cogent arguments for urging the necessity of control measures in the field whenever these are feasible and useful. Incidentally market pathology would be aiding production pathology while calling upon the latter to come to its aid.

One of the purposes of this paper is to present market pathology so that it may become coördinated with production pathology both from the field and from the teaching standpoint. With this in mind it is necessary for us to present the point of view adopted and explain the terminology now in use.

## II. MARKET DISEASES OF VEGETABLES

### *A. Nature and classification*

Our study has led us to group the market diseases rather arbitrarily into two classes. The first comprises the more or less specific and clearly defined field diseases or diseases, the causal organisms of which have rather narrow host limitation, such as bean anthracnose and eggplant fruit rot. The second class comprises the diseases not commonly recognized as of importance in the field, the causal organisms of which apparently are not narrowly limited as to host range and do not evince a high degree of parasitism as based upon virulence under field conditions. As examples of the latter group may be mentioned the bacterial soft rots and the Botrytis rot.

These two classes of diseases are not sharply delimited since such diseases as the Fusarium tuber rots, onion neck rot, and those caused by Rhizoctonia and Sclerotinia represent somewhat intermediate or at least connecting types.

The application of the term "disease" to rots or so-called "decay" may at first thought seem unjustifiable but, in view of the fact that fruits and vegetables are composed of living cells and tissues, invasion by rot-producing organisms may justly be termed disease despite the fact that predisposing factors may be essential to an extent generally not admitted in the orthodox conceptions of disease. Following Ward and Jones, we have chosen to define disease as any deviation from the normal structure or functions of plants or plant parts sufficient to threaten their life or impair their economic usefulness. Our definition provides for the very important

non-parasitic diseases or injuries such as those due to freezing and to sunscald.

Among the diseases of the first class it has developed that a considerable shifting of emphasis is necessary in the prevailing conceptions of their economic importance. From this standpoint a temporary grouping of these diseases may be made as follows: (1) Those in which the lesions may constitute objectionable blemishes without causing actual unsoundness, (radish black-root, potato scab, onion anthracnose, cucumber mosaic); (2) Those in which the lesions may serve as ports of entry for rot-producing organisms (bean blight, cucumber bacterial spot, tomato nailhead spot, tomato blossom-end rot); (3) Those in which the lesions may enlarge, under transit conditions, due to the invasion of sound tissue by the original organism, resulting in extensive rots (tomato Phoma rot, bean anthracnose).

With reference to the diseases of the second class, the so-called "rots," it is evident that microorganisms of very great economic importance have in the past received too little attention. As a first step toward a better understanding of such diseases, a study should be made of species or specialized races of the causal organisms.

Those diseases in either class which involve a rotting of the tissue are paramount in importance from a market point of view. The reasons for the destructiveness of the organisms which cause these rots may be found in the effect of the environment created by harvesting and marketing conditions upon the physiology of both host and parasite. The metabolism and the chemical and physical constitution of fruits and vegetables in transit are altered. Maturation and the ripening processes go on under very abnormal and at times unfavorable conditions. Cut off from their supply of water, minerals, and sunlight, succulent plant parts especially will not remain alive and resistant to parasitic attack very long and may be considered to be in a moribund state which is greatly aggravated by the conditions of transit. Further predisposition to the invasion by rot-producing organisms is effected by the wounds and injuries which are almost inevitable results of harvesting and handling operations as well as by the climatic influences to which such products are subjected. The conditions of high temperature and humidity which during transit often result from the continued respiration and transpiration of fruits and vegetables within confined quarters greatly favor the growth of most bacteria and fungi. The high humidity with resultant "sweating" or condensation not only favors bacterial and fungous development and invasion but also moistens the dead tissues of wounds and injuries and thus facilitates infection through such channels.

The very nature of these predisposing factors explains the control and prevention measures which are empirically recognized, viz., proper timing of harvest; avoidance of handling injuries; reduction of transit time; tem-

perature control by refrigeration, heating, or ventilation; and humidity control by ventilation.

For the use of the market inspection service it became at once necessary to adopt some simple name by which to designate each disease found in the markets. In the case of the diseases of the first class, some name already in use has as a rule been adopted. In the case of the general diseases of the second class, it was necessary to apply temporarily some usable descriptive name to serve until further study should necessitate alterations. There are four such general diseases of vegetables which we will characterize briefly.

*1. Slimy soft rot.* Under this term have been grouped all of the bacterial soft rots. These rots are characterized by the fact that the disintegrated tissue, when rubbed between the fingers, is first slippery, becoming slimy and later distinctly sticky. Generally they are also accompanied by a very foul odor, which, even if not pronounced in the very early stages, always becomes so later. The former characteristic is most marked in leafy chlorophyllous tissue while the latter is most pronounced in root, tuber, and leafy storage tissues. It is assumed for the present that this rot is due to bacteria of the *B. carotovorous* group, although it is notknown whether or not two classes may exist, namely, the soft rot of storage parenchyma (roots, stems, leaves, and fruit) and the slippery rot of chlorophyllous tissue. Slimy soft rot occurs in a variety of vegetable products and its inception and progress are favored by the presence of wounds (cabbage stump) and killed tissue (frozen or scalded areas) and by rather high temperature and excessive moisture. In the southern-grown leafy crops packed with ice in barrels or crates, the conditions of excessive humidity, thorough wetting of all surfaces, and a maximum of bruising, must favor the inception of slimy soft rot while the refrigeration obtained is at best imperfect.

*2. Watery soft rot.* This is the term adopted for the rots caused by *Sclerotinia libertiana*. The rot is characterized by the absence of any foreign odor, by the fact that the rotted tissue tends to yield abundant water under pressure and shrinks remarkably upon drying, and by the presence of the white fungous mycelium and black sclerotia. In the case of lettuce and celery this disease may occur in the field in a well recognized form (drop or damping-off of lettuce, foot-rot or pink rot of celery). In the market it occurs on a wide variety of hosts. It is the prevalent vegetable rot at low temperatures and is the most important storage rot of root crops.

*3. Rhizopus rot.* Here are grouped the rots caused by Rhizopus species. This is a rapidly progressing soft rot which occurs prevalently at high temperatures and is recognizable by the character of the fungous outgrowth and the acid odor of the rotting tissue. Soft rot of sweet potatoes represents a special case of this disease.

*4. Gray mold rot.* This class includes the rots caused by Botrytis species. The rot is not of as wet a type as the above mentioned classes nor is it apparently as rapid in its progress. It is characterized by the gray velvety fungous outgrowth and by the absence of any marked odor. The rot progresses at low temperatures and is quite prevalent on aging tissues. A special case of this disease is represented by onion neck rot.

Certain non-parasitic diseases are significant in the market because of their occurrence on a great variety of vegetables. The most important of these are freezing injury, sunscald, asphyxiation, bruising, and injuries due to disturbances in the water relation of tissues. These are objectionable not only as blemishes but also, and in a more important sense, because the areas of killed tissue open the way for attack by rot-producing organisms.

### *B. Market diseases arranged according to hosts*

*Artichoke.* Gray mold rot was the only disease found in artichokes. It destroys the edible portions of the head and often causes very heavy losses.

*Asparagus.* A watery soft rot which frequently causes heavy losses was found in California shipments. Although a Sclerotinia was associated with this rot, the very offensive odor frequently noted indicated that bacteria also were present.

*Bean.* Watery soft rot due to Sclerotinia caused the heaviest losses in southern-grown stock. This disease is characterized by a matted growth of white mycelium among the pods in the hamper and is called "nesting" by the trade. Soil is probably the source of infection. The development and spread of the fungus in transit is favored by the packing of wet stock or by the condensation of moisture upon the pods. The growth of the fungus is not markedly checked by the temperatures attained in refrigerator cars (40–46°F.).

Anthracnose was second in importance and was especially bad in Florida shipments and in the early crop of Louisiana beans. Old lesions enlarge and the fungus sporulates profusely in transit. New lesions may develop in great abundance during transit. These are probably the result of infection occurring in the field and invisible at the time of packing although it is quite possible that actual infection may occur in the hamper if wet stock is packed or if there is enough condensation moisture present to drain down through the hamper.

Soil rot due to Rhizoctonia occurred frequently and occasionally caused heavy losses in southern shipments. The lesions of soil rot are brown and at first circular with a few concentric ridges. Usually there are only one or two lesions on a pod but these enlarge rapidly and may penetrate clear through the pod. This disease may also result in "nesting" in the hamper.

Bacterial blight was fairly common in beans from all regions. It seems to be important mainly as a blemish but occasionally the lesions are invaded by slimy soft rot.

Rhizopus rot was common in beans in the summer and caused a densely matted type of "nesting" in crates or hampers. It is most common in shipments that become heated either during or before shipment.

A browning of green pod beans in hampers, which is not due to parasitic causes occurs rather frequently on the market. The outer two or three cell layers are brown in color and apparently dead. A minute brown specking of the pods somewhat resembling the type of sunscald described by MacMillan has also been noted very often.

*Horse bean.* A pronounced black wart-like outgrowth occurred on these pods, the cause of which was not determined.

*Lima bean.* Pod spot due to *Diaporthe phaseolorum* was noted to some extent in the eastern markets.

*Beet.* Southern-grown beets, like other green or new vegetables, are shipped with the tops intact. The greatest losses were due to slimy soft rot of the leaves. This is the type of bacterial soft rot which was responsible for most of the heavy losses in green vegetable crops shipped from the southern states. Although the edible portions, the roots, are not affected, they are rendered unsalable.

Black rot caused by *Phoma betae* and watery soft rot due to Sclerotinia occurred to some extent in locally grown roots when they were taken out of storage. Black rot is characterized by the firm, black nature of the affected tissue while in Sclerotinia rot the affected tissue is rather tough and spongy, shrunken or dried out, and brown in color.

Leaf spot was not encountered in the market to any extent.

*Mangel.* Extensive rotting due to Sclerotinia occurred in storage.

*Brussels sprouts.* Ring spot caused by *Mycosphaerella brassicicola* with its conspicuous green color and rings of black dots was often found as a blemish. A single lesion frequently covers the entire side of a bud. In repacking the contents of the iced drums as received from California, a very considerable quantity of the "sprouts" was discarded because of slimy soft rot. Black leaf spot due to *Alternaria brassicae* was found very frequently.

*Cabbage.* The greatest losses in cabbage were due to slimy soft rot. This may occur as a rather shallow rot of the outer leaves or as a more aggressive invasion of the stem pith from the cut stump. The rot seems to follow bruises, wounds, and freezing injury as well as other diseases such as yellows and black rot, and is favored by overheating and high humidity in the cars. Freezing injury is usually confined to the stem pith and interior portions of the head, the outer leaves apparently being able to re-

cover, while the killed interior tissues are very subject to soft rot infection. Slimy soft rot is particularly objectionable in cabbage because of the offensive odor. This rot may be controlled by drying all cut and bruised surfaces previous to loading, and by proper ventilation and refrigeration in transit.

Next in importance was watery soft rot due to Sclerotinia. It caused heavy losses in Florida, California, New York, and Wisconsin shipments. The fungus grows well under transit refrigeration and covers the outer portions of the affected heads with a dense white mycelium dotted with characteristically large sclerotia.

Black rot caused by *Pseudomonas campestris* was not found to be of great importance in the market. It is restricted to heads infected in the field. However, such heads are worthless since the infection is likely to be present in the inner leaves and cannot be eliminated by stripping off the outer leaves as in the case of certain types of slimy soft rot. This disease caused considerable loss in Florida Wakefield cabbage received in the northern markets.

Black leaf spot due to *Alternaria brassicae* was very prevalent in cabbage from all regions and was the source of a very appreciable deterioration in value of shipments since the lesions enlarge greatly during storage and transit and penetrate through several underlying leaves. These lesions are very unsightly and a severe stripping of the heads is necessary to prepare affected heads for sale.

Rhizopus rot was common in stock which became heated during transit and in improperly refrigerated cars during hot weather. Gray mold rot was important in cars showing a high humidity with resultant "sweating" of the stock and was also found in aging stock especially if this had been in storage for a long time. While both of these rots are generally confined to the outer leaves they usually render the stock more or less unsalable.

An extensive dotting of the leaves with very small, sunken, black spots which apparently are nonparasitic in origin has been termed leaf speck. It occurred in cabbage from all regions. Unless all leaves of the head are affected it is considered only a minor blemish.

*Carrot.* The greatest losses both in home-grown stored roots and in southern-grown stock shipped with the tops intact in hampers or barrels were due to watery soft rot caused by Sclerotinia. This fungus grows vigorously and profusely in carrots, especially under cool damp storage conditions, and progresses rapidly by mycelial growth from rotted to sound roots. The green tops are also attacked in the hampers. Extensive "nesting" is usually produced.

Under warm conditions a Rhizopus rot of the leaves and roots of southern stock was frequently found. Both gray mold rot and slimy soft rot

occurred toward the end of the storage season in northern-grown roots. The latter usually is restricted to the central cylinder of the root. These rots necessitate careful sorting of stored roots with attendant loss.

*Cauliflower.* In western-grown cauliflower, the principal trouble was due to its arrival on the market with leaves quite yellow, a condition known as "overmaturity" by the trade. In addition there occurred in transit some elongation or second growth of the pedicels. This condition is referred to as "ricey."

The heads often show numerous small browned dead areas from which an Alternaria has been isolated. Gray mold rot also often occurred on aging heads. Ring spot of the foliage caused by *Mycosphaerella brassicicola* was very prevalent in California and Oregon shipments. It not only detracts from the appearance of the stock but also is associated with premature yellowing and drying of the leaves.

*Celery.* Enormous losses were caused in Florida, California, and New York celery by watery soft rot due to Sclerotinia. This fungus grows rapidly under transit conditions and spreads throughout entire crates and from crate to crate by mycelial growth. The water literally can be wrung out of affected bunches and often drips from the doors of the cars.

Late blight due to Septoria caused great losses in celery from all regions, especially Florida and California, not only because of the unsightly spots on the petioles and leaf blades, but also because of a slowly advancing soft rot which is associated with these lesions. The disease develops and possibly spreads in transit since the fungus grows well at the temperatures attained in refrigerator cars. In the preparation of Florida celery for the market, extensive stripping of the outer leaves is necessitated because of the disease.

Slimy soft rot was found to be third in importance and was common in stock injured by freezing or by field diseases. It is most destructive under warm conditions.

In early blight caused by *Cercospora apii*, the lesions disfigure the leaf blades and petioles and lead to an objectionable loss in turgidity and crispness of the tissues. This disease occurred in Florida and California celery and was especially serious in the latter where it caused much loss due to the necessity of stripping off the outer leaves as in the case of late blight.

Bacterial spot was destructive in Michigan and New York celery both as a blemish on the leaf blades and also as the cause of large elongated petiole lesions in which the tissue is brown and watersoaked. Affected stalks are not considered fit for food.

Black heart was found only infrequently in the markets. It occurred in late shipments from Florida of the Golden Heart variety.

*Celeriac.* Late blight caused by Septoria was found to produce a conspicuous leaf spot of this host.

*Cucumber.* In southern-grown slicing cucumbers, the heaviest losses are due to bacterial spot caused by *Bacterium lachrymans* and the secondary soft rot which generally invades the lesions caused by this bacterium. Anthracnose also was present to a considerable extent on Louisiana stock. Fruit affected with anthracnose rapidly becomes unsalable because the later stages of the disease are marked by rapid rotting. Practically no scab was noted in the market although the disease is known to be sporadically destructive in the northern-grown pickle crop.

Rhizopus rot, a rot from which a Fusarium has been isolated and which progresses rapidly, and bacterial rots not associated with the spot caused by *Bacterium lachrymans* were found frequently in cucumbers shipped from Florida.

Mosaic was very prevalent in cucumbers in all the markets visited. It was noted that the early shipments from all districts were practically free of the disease. While mosaic fruits are not considered unsound nor inedible, their market value is reduced 50 per cent or more. Judging from the abundance of such fruits in the market, the losses in yield in the Chicago district must have been tremendous in 1918.

*Eggplant.* Extremely severe losses were incurred in shipments of this fancy-priced commodity by fruit rot due to *Phomopsis vexans.* Eight cars arriving in New York at one time from the Isle of Pines were a total loss because of this rot. This disease has almost ruined the eggplant industry of the Fort Myers, Florida, district. The rot progresses very rapidly under transit and market conditions and affords a striking example of a field disease which is exceedingly destructive in the harvested product.

*Escarole.* As in radishes, shallots, and spinach, great losses due to slimy soft rot occurred in escarole shipped from the south in iced barrels. In one case noted, such barrels were selling for fifty cents each, which was not enough to cover the freight charges nor the cost of the barrels. In some shipments a rather characteristic black leaf spot was found from which no fungus could be isolated.

*Chicory* or *curled endive.* Slimy soft rot frequently caused the loss of stock that had been retained too long in the market.

*Kohlrabi.* Watery soft rot due to Sclerotinia was found on kohlrabi in the market as well as a type of injury consisting of small, black, sunken spots rather uniformly distributed over the surface of the head.

*Lettuce.* Tremendous losses in Florida, Louisiana, California, and New York lettuce were caused by slimy soft rot. As many as 2500 hampers of Louisiana lettuce were rejected at the car door in Chicago in one week. The etiology of the various forms of this rot has not been determined but

it seems quite probable that tipburn, especially on the interior leaves, is one of the important predisposing factors. The leaf spot caused by a yellow bacterium also predisposes the leaves to slimy soft rot.

Watery soft rot caused by Sclerotinia was very prevalent in Florida and Louisiana stock arriving early in the season. This rot is favored by a wet pack with much soil present. It is attributable to soil infestation and progresses rapidly even in refrigerator cars where it spreads by mycelial growth.

Tipburn of the inner leaves was a common and very objectionable feature of head lettuce on the market. It is economically important not only because the dead leaf margins reduce the desirability of the heads for table use but especially because the killed tissues in the moist interior of the head are readily invaded by bacteria that cause slimy soft rot.

A watersoaking and subsequent rotting of the outer leaves is often caused by Botrytis. This condition necessitated considerable stripping of the heads at destination. A type of blemish consisting of numerous small brown spots and streaks along the midribs of all of the leaves was of common occurrence. It lowers the quality of affected stock very appreciably. This has been termed "russet" and apparently is non-parasitic in origin.

A rather characteristic leaf spot, of which the etiology is not known, was found on Romaine lettuce. Downy mildew caused by *Bremia lactucae* was sometimes found in Grand Rapids forcing lettuce from northern hothouses and in California head lettuce. It was not found frequently in the market probably because its attack is largely confined to the outer leaves which are stripped off in preparing the plants for market. However, the mildew undoubtedly predisposes the stock to Botrytis rot of the outer leaves.

*Muskmelon, Cantaloupe.* Anthracnose was not noted on southern-grown cantaloupes but occurred to a serious degree on Colorado Rocky-Fords. Occasionally cantaloupes were rotted by a Fusarium which showed abundant superficial mycelium. Cases were also noted during the summer in which the melons showed lesions with a considerable external development of Cladosporium, which did not however resemble the attack of the scab fungus.

*Casaba melon.* Among the very expensive California Casaba and Christmas or Santa Claus melons, very great losses were caused by a characteristic fruit spot due to an Alternaria. The oval to circular, brown to black, sunken lesions were accompanied by a slowly advancing dry rot of the underlying rind tissues. This disease seemed to be especially destructive in melons held in cold storage. The relation of this fungus to the Alternaria blight of the vines in the field has not been determined.

*Honeydew melon.* Anthracnose was the most important disease of southern honeydew melons. The lesions not only lessen the value of the fruit but soon render it unsalable. Considerable reduction in market value of melons was also found to be caused by an Alternaria which usually followed sunscald and was accompanied by a dark brown to black surface development of mold.

Heavy losses in western honeydew melons were due to the prevalence of a fruit spot caused by an Alternaria. The lesions were similar to those noted on the Casaba melons and the same fungus was found associated with them. On an occasional specimen a rapidly progressing Fusarium rot was found. This fungus rots the stem end producing an abundant pink mycelium in the rotted tissues.

*Mustard.* The chief losses in shipments from the south were due to a tendency of the leaves to turn yellow in transit.

*Okra.* At times a destructive soft rot due to an undetermined fungus was found.

*Onion.* In California and Texas onions, the greatest losses undoubtedly were due to slimy soft rot. In California onions from the Stockton district this rot followed sunscald. At times entire carlots were salvaged only with great difficulty by spreading the foul-smelling contents of the bags upon the warehouse floor and checking the rot by rapid drying of the surfaces of the bulbs. In shipments from Texas, in which large losses occurred at harvest time in 1918, this rot followed wounds and sunscalding. In northern stock this rot follows freezing injury. Slimy soft rot may be external or limited to certain interior scales. Shallots, like other green vegetables shipped from Louisiana in iced barrels, are readily attacked by slimy soft rot of the tops and although the edible portions are not destroyed affected stock is worthless. The losses in shipments of shallots were extremely heavy. A similar rot of the leaves was also noted in homegrown boiler stock when retained in the market too long. Such stock usually is salvaged by cutting off the rotting tops.

Next in importance, among the market diseases of this crop, was black mold rot due to *Sterigmatocystis niger*. While this usually is a dry rot and not very aggressive it is of very general occurrence and the black spore masses constitute a serious blemish. Under moist conditions the rot is quite soft and develops rapidly. The spore masses are most frequently produced under the exterior scale and it is not at all strange that this disease should be generally known as "smut" by the trade. Black mold rot occurred in Texas, California, and Bermuda onions in transit and homegrown sets in storage and greatly lowers the market value of shipments showing any considerable percentage of affected bulbs. At times this rot causes very heavy losses. In the early winter a consignment of four cars

of Australian Brown onions shipped from Stockton, California, to New York were rejected on one day because of this rot.

In northern grown onions, neck rot due to Botrytis or Sclerotium probably caused the most serious losses because of its development during storage. Although affected stock is often sorted before it is sent to market, the disease was frequently found in the stock on sale. Neck rot was found especially destructive in onion sets.

Smudge or anthracnose caused by *Colletotrichum circinans* was extremely prevalent among the northern-grown white varieties. It is not only objectionable as a blemish, but in sets was found to lead to rotting of the outer scales under moist storage conditions.

A Fusarium rot occurred rather commonly in onion sets and in table stock. A blue mold rot was found on sets and also on table stock which had been held under warm humid conditions during storage or transit. Louisiana shallots shipped north in barrels were frequently found rotted by a Botrytis which completely covered them with its characteristic gray velvety growth. On red and yellow northern grown onions a Macrosporium was found to cause lesions on the outer scales. This disease has been called "blotch" by Dr. J. C. Walker. It usually constitutes only a minor blemish.

Sets affected with smut were only occasionally found. They are greatly shrunken, very light in weight, and worthless. Such specimens are a source of danger from the standpoint of dissemination of this very serious field disease.

On the winter crop of onions, especially in the market gardens about St. Louis and Kansas City, there occurred a rather serious blemish due to the attack of a Botrytis at the ground line of the plants. The lesions are very conspicuous because of the extensive red discoloration of the tissues. The attack results in the death of the outer leaf.

Freezing injury in onions, usually confined to one or two outer scales and recognizable by the watersoaked appearance and softening of affected scales, caused very heavy losses. It was found to predispose onions to Botrytis and slimy soft rot. The tendency of onions to sprout during storage was found a source of very great loss and the relation between this tendency and the presence of certain diseases is well worthy of study.

*Parsnip.* The principal loss in parsnips in storage was caused by watery soft rot due to Sclerotinia. Even after the roots are sorted and washed for display this fungus continues to develop and spread from lesions which were overlooked in sorting. Gray mold rot also occurred to some extent in parsnips, especially after they had been removed from storage.

Freezing injury was found to cause considerable depreciation in the market value of parsnips. This injury is marked by a gray watersoaked

discoloration and softening of the surface tissues about the large end of the root and is not only objectionable in itself but renders the killed tissue subject to fungous invasion.

*Pea.* The rather large, greasy, watersoaked lesions of bacterial spot occurred very commonly in the market especially in the northern-grown crop. These constitute a very objectionable blemish and predispose the stock to secondary invasion.

The most common rot in the market was found to be watery soft rot due to Sclerotinia which with its characteristic "nesting" of the pods resembles the similar rot of beans. It does not however occur as frequently on peas as on beans.

The circular, sunken, brown to pink centered lesions of the Ascochyta blight were found occasionally in the market. They frequently were prevalent in California stock. The disease greatly lowers the market value of affected peas.

*Pepper.* A variety of green pepper diseases was found in the markets. Without doubt the greatest losses were due to Rhizopus rot, which progresses very rapidly in both green and cayenne peppers in warm weather. In Ap il, 1918, on one day, four carloads of peppers from the Isle of Pines were dumped into New York harbor as a total loss because of Rhizopus rot. A slimy soft rot also has been noted in the markets. In addition several spot diseases were found. A sharply sunken brown lesion yielded an Alternaria in culture. A minute specking of the fruits (cause undetermined) was also noted. An elevated corky scab, apparently the bacterial spot disease reported from Florida in 1917 by Sherbakoff, was also found to a limited extent. Sunscald was very prevalent during midsummer and the large bleached areas often involved the entire side of a fruit. Anthracnose due to a Gloeosporium occurred frequently in southern-grown peppers.

*Potatoes.* Taking the potato crop as a whole, Fusarium tuber rots caused greater losses in storage and transit than all other potato diseases combined. In northern and western potatoes these losses are greatest toward the end of the storage season and are due largely to the powdery dry type of Fusarium rot, which is not checked by ordinary storage temperatures. Most of the Fusarium infections may be attributed to wounds due to rough handling, to freezing injury, and to secondary invasion of the lesions of black field rot, jelly-end rot, and leak in western stock and of late blight tuber rot in northern stock.

Two distinctly different types of Fusarium rot occurred to a serious extent in southern potatoes, which were marketed directly from the field. One is a dry firm rot of the stem-end resembling blackleg lesions in color, the other a watery soft rot of the entire tuber accompanied by an abun-

dant external mycelium and sclerotia-like sporodochia. The former resembles black field rot, the latter, the jelly-end rot of the west. Both have yielded *Fusarium radicicola* in culture. This rapidly progressing watery type of rot destroyed large quantities of potatoes in southern shipments in 1918. It seems to follow wounds and sunscald and is favored by hot weather. Frequently the vascular symptoms of Fusarium-blight were found in potatoes in the market. Unless these are associated with tuber rot they are of minor importance from a market point of view.

In the southern crop, however, slimy soft rot or bacterial soft rot was by far the most serious transit disease. This very offensive rot is particularly destructive since not only are the affected tubers worthless, but the whole sack or carload may become so smeared that the difficulty and expense of attempting to sort out and salvage the sound tubers may entail as great a loss as the value of the stock actually destroyed. This type of rot seems to originate in rather extended surface areas of the tuber and as a rule follows scald or deep scald. Shipments which arrived in Chicago in July suffered great depreciation because of slimy soft rot. In western and northern stock, slimy soft rot occurred in the tubers killed by freezing injury. It is the usual condition in which the so-called "field-frosted" tubers reach the market.

Certain types of non-parasitic injury to which potatoes are subject were found extremely important, not only in themselves, but also as factors which predispose tubers to the above mentioned rots.

Freezing injury was the cause of very great losses in potatoes not only in its extreme form, involving the killing and softening of the tuber, but also in its less conspicuous forms such as bluish gray internal regions which often turn black when cooked, slightly sunken, shallow, surface lesions, and the net necrosis type of injury. These internal symptoms of freezing injury practically always may be detected by cutting across the stem end of the tuber since that end seems more sensitive to freezing. In such winters as that of 1917–1918, the losses from freezing in transit are enormous.

Injury due to rough handling, cuts, fork wounds, crushing with the resultant fracture known as "splits," and to the breaking off of second growth knobs was found to be responsible for a large proportion of the Fusarium rots in the storage crop.

In southern grown potatoes in 1918, scald was extremely prevalent. This consists of a killing of the superficial tissues over rather extended areas with subsequent shrinkage so that the end result is a sunken surface lesion of irregular outline somewhat suggestive of a late blight lesion. Deep scald, also common and very destructive in southern potatoes, involves the death and discoloration of a considerable portion of the tuber. This is

known as "blue-belly" by the trade. Its cause has not been determined. It was found in the field in Florida by the senior writer and near East St. Louis, Illinois, by Dr. V. H. Young, Both scald and deep scald are commonly followed by slimy soft rot or the watery type of Fusarium rot.

Black-heart, which results from allowing stove-heated cars to become too hot, was frequently found in those parts of the load which were near the stove. Occasionally an entire car was found affected with black-heart.

In addition to the first two types of rot described, there are three others which were frequently encountered in transit, viz, late blight tuber rot, brown rot, and leak. Late blight tuber rot was a serious source of loss in Maine and Florida shipments, not only because of the Phytophthora lesions in themselves, but also because of the importance of these in predisposing tubers to Fusarium and bacterial rots. The appearance of late blight tuber rot in the freshly dug Florida potatoes arriving in the market was deceiving since the characteristic surface depression was absent. Infection of this nature can be detected only by cutting the tubers or by scraping the surface to reveal the chestnut-brown tissue discoloration.

Brown rot due to *Bacillus solanacearum* occurred only in Florida shipments. Affected tubers usually are worthless because of the cavities of soft rotted tissue associated with the vascular ring. In less advanced cases, abundant gray bacterial slime exudes from the vascular bundles when the tuber is cut.

The western leak due to *Pythium debaryanum* and Rhizopus was found in Stockton, California, potatoes marketed in western markets and in Idaho stock shipped into the markets of the middle west. Some leak was found in Montana potatoes.

Common scab, because of its constant prevalence and widespread occurrence, was found to be of very great importance. Even though it is more or less superficial and does not predispose to rot infection, scab is a very objectionable blemish and materially lowers the grade and quality of a large proportion of the potato crop. Still more objectionable but less prevalent is the so-called deep scab, which necessitates deep paring and even excision of lesions with attendant waste.

Similar to scab in their effect upon the quality of affected stock are flea-beetle injury (recognizable by the corky splinters which penetrate the cortex to a depth of from 1 to 10 mm.), wire worm channels, white grub cavities, and nematode injury.

Rhizoctonia was very generally present in potatoes from all regions. It is least common in southern potatoes. In western potatoes, russet scab, which is possibly due to Rhizoctonia, occurred frequently. This is in advanced stages a deep checking of the surface, suggestive of alligator

hide, and is unsightly and also necessitates deep paring. In its sclerotial or black scurf form, the Rhizoctonia disease is extremely common but the fungus is superficial and consequently it is generally ignored on the market. Potatoes must be very severely spotted with sclerotia before their market value is reduced by the presence of Rhizoctonia. Under certain conditions of transit a luxuriant development of aerial mycelium was found to arise from the sclerotia. This caused a very heavy depreciation in the value of the potatoes. A similar depreciation due to the aerial development of other superficial fungi such as Penicillium was frequently noted in cut and bruised stock. Buyers prefer clean dry stock.

Certain non-parasitic troubles were also found to distinctly lower the quality of potatoes. Of these, hollow heart, which is especially prevalent in the large western grown varieties, was the most common and most serious. In these varieties second growth knobs and growth cracks also were factors which lowered the quality. Internal brown spot and net necrosis were found in the market to some extent. Like hollow heart their presence is not evident until the tubers are cut and usually the loss due to such defect, falls upon the ultimate purchaser.

In tubers exposed to sunlight in the field or during storage and transit, the surface becomes green in color due to the formation of chlorophyll in a few cell layers. This is called sunburn or greening and was found objectionable in table stock because of the bad flavor due to the greening. Salt injury occurred frequently in potato shipments. It is found in potatoes next to the floor or sides of a car that has been previously used for shipping hides, fertilizers, or salt. Affected tubers become soft and flabby and the salt may be detected by tasting the affected tissues. The lesions probably are due more to plasmolysis of the tissues than to the toxic effect of the salts. Affected tubers are worthless and soon become infected with slimy soft rot. Excessive peeling due to immaturity was found to be an undesirable characteristic in the market. Enlarged lenticels were frequently found. This condition is usually considered no more than a blemish.

*Radish.* Undoubtedly, the greatest losses in radishes occurred in the Louisiana crop, which is shipped packed in barrels in crushed ice. These losses were due entirely to slimy soft rot of the tops. Affected bunches are worthless in the market although the edible portions are perfectly sound.

Black-root was found to be of considerable importance in the market, especially in the white radishes, although the red varieties are susceptible. While the diseased tissue is not disintegrated, the black color and the cracked misshapen character render such specimens unsuitable for table use and reduce the desirability of bunches in which these occur.

Occasionally a root was found bearing the circular, brown lesion of Rhizoctonia rot. Downy mildew and white rust occurred frequently on

the leaves but appeared to be of no importance in the market. The black winter or storage radishes when removed from storage were occasionally affected with a fungous rot which has not yet been studied.

*Rhubarb.* Extensive losses in the rhubarb shipped from Illinois points were caused by a fungous rot which progresses rapidly under transit and market conditions. In one instance 28 crates were a total loss due to this trouble. Close examination showed that the rotted areas usually centered about characteristic lesions on the stalks. Investigation of the fields from which shipments were being made revealed that these elliptical, sunken, petiole lesions were prevalent on the plants of all ages, as was likewise a circular reddish brown leaf spot. With the disease in the field as well as the rot in the market was found associated a pycnidial fungus resembling Ascochyta.

Gray mold rot and slimy soft rot were frequently found in the market.

*Rutabaga.* Rhizoctonia was found causing considerable rotting in rutabagas. Carload shipments of these roots in bulk often show a high loss due to a variety of rots, the most important of which is slimy soft rot. Wounds and freezing injury are thought to be the principal predisposing factors. Fusarium species play an important rôle in the undetermined flora of rutabaga rots.

*Salsify.* Watery soft rot due to Sclerotinia occurred rather frequently in salsify in the market. Storage rots of other types have also been noted.

*Spinach.* The heaviest losses in spinach occurred in the Louisiana crop which is shipped packed in crushed ice. These losses are due to slimy soft rot which progresses very rapidly under these transit conditions. The nature of the pack affords an abundance of water and wounds, two factors known to favor this type of rot. The Colletotrichum spot was noted in the northern grown crop and occasionally spinach blight was seen in the market.

*Squash.* Hubbard squashes late in the fall have exhibited a rather varied fungous flora, of which Rhizopus seemed to be the most important in the production of decay. Botrytis was noted as well as a rather common pycnidial fungus which produces pink spore masses. Rhizopus rot was also found among summer squashes of the white bush scallop type, usually following wounds.

*Sweet potato.* The most destructive market disease of sweet potatoes was Rhizopus rot or the so-called soft rot. This rot is very destructive under warm conditions especially in humid overheated cars and necessitates repeated sorting of the stock in the market.

The shallow, hard, dry lesions of black rot caused by *Sphaeronema fimbriatum* were very common on eastern grown roots and while this is not a

very active rot, nevertheless it is an important one. The lesions must be cut out carefully before the roots are cooked because of the acrid flavor imparted to an entire lot by a few lesions. Scurf caused by *Monilochaetes infuscans* is a minor blemish and was often found. The trade pays but little attention to it. Occasionally examples of stem rot, foot rot, and pox were found. Dry rots from which Fusarium species were isolated were very frequently found.

*Tomato.* Despite the care with which tomatoes are handled, great losses occurred in the stock from all regions, largely due to diseases of field origin. Tomatoes are not shipped under refrigeration because it is assumed by tomato dealers that the ripening processes are interfered with. Tomatoes are picked in the pink stage and upon delivery are sorted for condition and maturity, the diseased fruits being discarded as a total loss ("rots") or as a partial loss ("specks"). An estimate of 15 to 20 per cent as the average loss occurring in the sorting rooms is conservative. After being sorted tomatoes are put into ripening rooms to bring them to a red color. Our observations lead us to believe that the ripening processes are interfered with by refrigeration to such an extent that they lose out in the race with Phoma rot and other diseases when the fruit is taken out of refrigeration and placed in the ripening rooms.

Soil rot caused by Rhizoctonia, appearing as it does in shipments from almost all regions and especially the South and California, probably caused more losses in the market than any other single factor. The large brown lesions, aptly termed "water blisters" or "water rot" by the trade, render affected fruit worthless. The fungus grows very rapidly under transit conditions and the luxuriant development of aerial mycelium results in the infection of neighboring fruits in the pack in spite of the paper wrappers since the fungus is able to penetrate these.

The rot caused by *Phoma destructiva* was found to be the greatest loss-producing factor in shipments of Florida tomatoes. This disease also occurs in California tomatoes. Infection apparently takes place previous to wrapping of the fruit and the black, sunken lesions enlarge very rapidly during transit and in the ripening rooms. Affected fruits are salable only as culls or so-called "specks," at a very low price. In the early Florida crop the lesions usually occur about the stem end. Later in the season they are well scattered over the entire surface of the fruit. Nailhead lesions almost invariably become infected with Phoma rot in fruit shipped late in the season.

While not a rot, nailhead spot caused by *Macrosporium solani* was found second in importance as a loss-producing factor in Florida tomatoes because the lesions are not only bad blemishes but also open the way for invasion by rot-producing fungi, especially Phoma.

In the Texas and central Mississippi valley tomatoes, the heaviest losses were due to the prevalence of the non-parasitic blossom-end rot, which in four cases out of five is infected by some rot-producing organism by the time the fruit reaches market or leaves the ripening room. Growth cracks were found to be of almost equal importance because of their liability to infection. Sunscald was also a prevalent blemish on tomatoes from these regions and likewise commonly resulted in the infection of the fruit by some fungus. Catface, a blemish almost as prevalent as growth cracks in certain varieties, rarely exposes the fruit to infection.

In California tomatoes, severe losses were caused by a non-parasitic mottling of the fruit supposedly due to the mosaic disease. While such fruits are unsightly, the affected tissue is usually sound when the shipments arrive but since dealers know from experience that affected fruits will not ripen properly they discard them as a total loss. Affected fruits are particularly subject to infection by various fungi such as Phoma, Alternaria and Cladosporium.

Anthracnose was an important cause of loss in ripe northern-grown tomatoes. The lesions are not as conspicuous as those of Phoma rot and enlarge much less rapidly so that the affected fruit can usually be disposed of for immediate consumption. This disease is of common occurrence in the fruit on display in retail stores in the summer. Anthracnose also is prevalent in California shipments.

During hot weather the very soft rot due to Rhizopus was of frequent occurrence. Affected fruits are usually well disintegrated when unpacked so that they not only constitute a total loss but by wetting the wrappers of the other fruits very seriously impair the appearance of the pack. Sporulation is rather uncommon but the fungus is able to pass through the wrappers from fruit to fruit. Other rots found to be of importance in the market are black mold rot due to species of Alternaria, buckeye rot due to *Phytophthora terrestria*, a rot due to Fusarium species, and a Cladosporium following mosaic and anthracnose in California stock, and various other undescribed, foul-smelling rots.

A very striking disease was found in Cuban tomatoes, which was called ring rot because of its large circular lesions with conspicuous concentric markings. This is thought to be due to a Melanconium and may be the same as the greenhouse disease described by Tisdale. Other minor blemishes of infrequent occurrence have been termed "speck," "blotch," and "canker." The etiology of none of these is understood at present. On the yellow pear tomatoes definite brown lesions have been noted with which a pycnidial fungus was associated. The identity of this fungus has not been determined.

*Turnip.* A brown rot caused by Rhizoctonia occurred on turnips in the market as did the typical slimy soft rot. Both seem to be associated with injuries.

*Watermelon.* Of the two important diseases of watermelons causing losses in the market, stem end rot due to Diplodia was the more destructive. This rot advances rapidly under transit conditions and affected fruits are rejected in the car. During the last season the loss from four states alone was 2500 cars valued at one and a quarter million dollars.

Anthracnose, which develops rapidly under transit conditions, was found to be much more prevalent than stem-end rot though less destructive, since affected fruits are usually salable. Anthracnose as found in the market results from field infection which was more or less inconspicuous at the time of loading. The sunken lesions are not only unsightly but eventually penetrate the flesh and in addition also open the way for more rapidly progressing rots. Of the latter a sour smelling fermentation of undetermined cause is sometimes found. Random inspection of numerous cars on the Chicago team tracks has sometimes resulted in the failure to find a single car load free from anthracnose. This illustrates its prevalence and wide geographic distribution. It was found in the Los Angeles market in melons grown in the Imperial Valley of California and in melons at the loading station at Turlock, California. One car of melons from Florida upon arrival in Chicago showed 15 per cent stem-end rot and 90 per cent anthracnose and sold for $100.

Rhizopus and Sterigmatocystis have also been found in watermelons. They are most prevalent on sunscalded areas.

Botrytis rot has been found on northern grown citrons, possibly following freezing injury.

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# MOULDING OF SNOW-SMOTHERED NURSERY STOCK

CARL HARTLEY, ROY G. PIERCE AND GLENN G. HAHN

Death of the leaves of conifers, as well as of evergreen dicotyledons, packed for storage or transport, is rather common. Commonly spoken of as "heating," it is likely that in some cases heat due to proximity to boilers or developed by respiration in the mass of leaves has something to do with the trouble. It is thought that much of the damage is due to the work of weakly parasitic fungi such as *Trichothecium roseum* or *Botrytis cinerea*, which would not ordinarily attack the plants; the "sweating" or condensation of moisture on the leaves which sometimes takes place should facilitate the progress of fungi.

In conifers in situ there are also cases of loss in which smothering and parasites both seem to be concerned. In plants covered by *Scorias* sp. and *Thelephora laciniata* smothering is all that is known to occur. Smothering by snow, followed by the combined smothering and parasitism of *Herpotrichia nigra* and *Neopeckia coulteri*, have long been known to cause damage to conifers at high elevations. There is in addition considerable loss of coniferous nursery stock in some places, due either to smothering under mulch[1] or under snow, in which the direct cause of death appears to be parasitic. The present paper deals with the death of snow-covered conifers.

## DESCRIPTION OF INJURY

Weir states in a personal letter that the Botrytis which he reported[2] as attacking young forest Douglas fir (*Pseudotsuga taxifolia*) begins its work with the passing of the snow, and has been a cause of serious injury to Douglas fir stock in a Montana nursery on which the snow remained unusually long in the spring.

In the Cottonwood Nursery of the United States Forest Service, located at an elevation of 7300 feet on the west slope of the Wasatch Mountains, Utah, where the writers' work on this problem has been done, serious losses under the snow have been experienced in beds of Douglas fir. Engelmann spruce (*Picea engelmanni*), blue spruce (*Picea parryana*),

[1] Hartley, Carl, The blights of coniferous nursery stock, U. S. Dept. Agr., Bul. 44, p. 18, 1913.

[2] Weir, James R., A Botrytis on conifers in the Northwest. Phytopathology **2**: 215. 1912.

Norway spruce (*Picea excelsa*), western yellow pine[3] (*Pinus ponderosa*) and lodgepole pine[3] (*Pinus contorta*) have also suffered, but to a less extent. At this nursery the snow becomes many feet deep, and remains on the beds commonly for six, and sometimes for seven months. During a large part of the winter the soil is entirely thawed, and the snow constantly melting at the bottom. All small plants are pressed down against the wet soil surface by the settling snow. Most of them are, therefore, unfrozen but kept at a temperature of practically 0°C. Except in winters when the snow goes off earlier than usual, a great many of the seedlings less than one year old, and also of older plants which have been transplanted or "heeled in" during the preceding autumn, are found partly or entirely dead. As in the case of mulch injury, the roots are not affected till several weeks after the tops are killed. The older killed plants are covered with a dark mycelium, rather conspicuous but not dense, except on leaves already dead; scattered hyphae of what appears to be the same organism are found on the smaller seedlings. The diseased plants occur in groups, especially in the dense stands of the older seed beds, indicating spread from one plant to another during the winter. Close examination of one-year-old Douglas fir in different stages of disease gives especially strong indication that the immediate cause of death is a parasite. The normal course of the disease seems to include the infection of one or more cotyledons, from which the parasite works into the stem, thence extending both up and down the stem, rotting the bud, and spreading into other cotyledons and needles from the base outward. In some cases the spread from the base of the first needle infected to others seems to be through the most superficial stem tissues, leaving the stem and bud uninjured and with a chance for subsequent recovery. The cotyledons are often partly dead, and presumably infected with the snow-mould parasite, before the beds are permanently snow-covered in autumn. It is certain that during the cold wet weather of the first month following the disappearance of the snow in the spring, lesions already started on the one-year-old Douglas fir continue to spread, often resulting in the death of plants which showed only slight injury at the time the snow melted. No extension of the superficial dark mould occurs after the disappearance of the snow. With the resumption of growth by the seedlings, resistance evidently increases, and many of the injured seedlings recover.

### THE FUNGI CONCERNED

A number of fungi were obtained from recently diseased parts by cultural methods. Most of this work was done with the youngest Douglas-fir seedlings, as they suffered most from the disease. The smaller amount

[3] Information furnished by Mr. N. J. Fetherolf.

of work done on the older stock and on the spruces indicated that the same fungi were commonly present on them. The 3 commonest organisms were:

*Botrytis cinerea.* This was isolated from Douglas fir, and Engelmann and Norway spruce. Bodies resembling the sclerotia of this fungus were occasionally found on diseased seedlings in the seed-beds, and were also developed in moist chamber. The sporophores were commonly produced in moist chamber, and the fungus was obtained in culture both from spore dilutions, and from recently diseased tissue planted directly in nutrient agar. The more recently killed the tissue used for these agar plantings, and the more care employed in asepsis, the more commonly the Botrytis was secured. Spores developed in moist chamber measured approximately 7 by 10.5 $\mu$. Growth on cornmeal agar agreed with that of a strain of Botrytis from apple,[4] growing rapidly and forming numerous black sclerotia, but not fruiting in tube cultures.

An ascomycete with smooth, spherical, unbeaked, subsuperficial perithecia from 75 to 130 $\mu$ or occasionally more in diameter. It was isolated from Douglas fir. This fungus was abundant on the killed needles, but nearly all the perithecia were immature, and moist chamber treatment failed to mature them. The few found with spores were apparently aparaphysate; asci obclavate, 8-spored, about 20 by 60 $\mu$, with short stalks, and wall strongly thickened at the apex. The ascospores were 1–3 seriate, hyalin or granular, mostly 6 to 7 by 15 to 20 $\mu$, 1-septate, the 2 cells being equal in length but the cell nearer the base of the ascus having the lesser diameter. The scarcity of mature fruits, and the possibility that the ascospores seen would have become dark with greater age, made identification impracticable. What appeared to be this fungus was obtained in culture as a slow growing mycelium from an agar planting of diseased tissue. It formed abundant and apparently typical perithecia imbedded in the agar in the tube cultures, but none have been brought to maturity.

A sterile dark mould. This was isolated from Douglas fir and Engelmann spruce. It appeared commonly on diseased plants in moist chamber, and on agar plantings of diseased tissue, growing slowly but producing a strong aerial growth of hyphae, becoming olivaceous and later black. No fruits were secured, and the organism proved somewhat difficult to maintain in artificial culture, at least in warm weather. It is believed to be identical with the common dark mould on the surface of injured plants. The hyphae of the mould in the seed beds had a diameter ranging from 2 to 6.5$\mu$; in culture the range was from 2 to 4$\mu$. The hyphae somewhat resembled those of *Corticium vagum* in branching habit, but were smaller and darker.

[4] Obtained from Dr. J. S. Cooley.

Among fungi which occurred less commonly in the cultures were *Fusarium acuminatum* E. & E.[5] from Douglas fir, a Pestalozzia resembling *P. hartigii* from Douglas fir and Engelmann spruce, and a fungus with groups of conspicuously beaked pycnidia discharging pink masses of ellipsoid spores 2.5 by 5–8$\mu$.

### MINIMUM GROWTH TEMPERATURE OF THE FUNGI

Cultures on prune and cornmeal agar, of each of the six fungi mentioned above, and of four others obtained from the seedlings, were placed in incubator compartments at temperatures of 0° and 5°C. The sterile dark mould and the Botrytis both started good growth within three days, while with the exception of one of the Pestalozzia tubes in the warmer compartment none of the other organisms made a perceptible growth. After the third day the temperatures fluctuated, each compartment at times going as high as 5° above the point at which it was started. By the tenth day all the fungi had made measurable growth. In the colder compartment, the Botrytis and the dark mould had made a decidedly better growth than any of the others; furthermore the dark mould had made a radial growth of 6 mm. in the colder chamber as against 7 mm. in the warmer, and the Botrytis had actually made as fast growth in the colder chamber as in the warmer. It appears from this preliminary test that the Botrytis and the dark mould are both especially well able to grow at low temperatures, and while the other fungi were also able to grow at rather low temperatures, the reasons for suspecting pathogenicity from these two under the melting snow were rather increased.

### INOCULATION EXPERIMENTS

Approximately 200 two-year-old Douglas fir seedlings were obtained in the autumn from the Cottonwood Nursery where the disease had been doing damage, and used in an inoculation experiment under somewhat similar conditions to those prevailing at the nursery. The plants were first washed, and the considerable number of dead needles already present were carefully removed with sterile scissors. The seedlings were then packed tightly into test tubes and inoculated with mycelium from prune agar cultures of all the fungi which had been obtained in culture. Sterile prune agar was placed on the seedlings in part of the control tubes. The tubes were tightly plugged with cotton, kept in an ordinary refrigerator for six days, and thereafter part of them in the 0° compartment and part in

[5] Determined by Mr. C. W. Carpenter.

the 5° compartment of the refrigerator used by Brooks and Cooley.[6] In addition, 1000 one-year-old seedlings of the same species from a Colorado nursery where the snow injury seldom occurs were inoculated in the same way, and put directly into the 0° and 5° compartments. These seedlings were in better shape than the two-year stock, and required very little trimming. The older plants were kept at the controlled temperatures for eleven weeks, and the younger for eight weeks. At the end of that time mycelium and dead needles were visible in all tubes, especially those which had been kept at the higher temperature. Some of the seedlings were entirely dead. There was no observable difference between the inoculated seedlings, the controls to which agar had been added, and the controls without agar. One or more organisms capable of attacking the seedlings under the conditions of the experiment were evidently universally present at the beginning of the experiment.

In a single test with a relatively small number of two-year-old seedlings, which had been washed in 3 per cent hydrogen peroxide before inoculation, more satisfactory results were secured. At both 0° and 5° the controls, both with and without the addition of agar, showed a little dead leaf tissue, but the seedlings inoculated with the dark mould and the Botrytis showed a decidedly larger amount. Sclerotia developed on the seedlings inoculated with the Botrytis and held at 0°. No other fungi were tested. Repetition of this experiment on a large scale with one-year-old seedlings and all the suspected organisms is desirable.

## FACTORS INFLUENCING SNOW MOULD

The resistance of the host to the disease appears to be influenced both by its age, the condition of its roots, and the length of time it has been subjected to snow cover. One-year-old Douglas fir appears more susceptible to injury than older stock. Plants transplanted or heeled in the fall, and therefore deprived of much of their root system, appear especially susceptible. The greatest injury is reported to occur when the snow lies on the beds from two to four weeks beyond the normal time. Partly as a result of their observation on this point, forest officers have adopted the practice of sprinkling black soil on the surface of the snow in early spring, with the result of materially hastening the disappearance of the snow.

In spite of the apparent fact that the disease often spreads directly from diseased to healthy seedlings, more damage in one-year-old beds has been observed in thin or moderate stands than in dense stands. Following the winter of 1914–1915 in which loss was unusually light, counts of the dead

[6] Brooks, Charles, and Cooley, J. S., Temperature relations of apple-rot fungi. Jour. Agr. Research **8**: 141–142. 1917.

seedlings were made in 30 unsprayed plats, of $7\frac{1}{2}$ square feet each, scattered at regular intervals through the experimental beds. A year later counts were made on 8 small unsprayed plats each 1 square foot only. The stand densities varied from 50 to over 250 seedlings per square foot. The percentage dead in plats with different densities follows:

(Figures in parentheses indicate number of plats on which each average is based.)

50– 90 seedlings per square foot.... 1915, 8.5% dead (4); 1916, ..... (0)
90–130 seedlings per square foot.... 1915, 8.6% dead (9); 1916, 23.6% (2)
130–170 seedlings per square foot.... 1915, 9.0% dead (7); 1916, ..... (0)
170–210 seedlings per square foot.... 1915, 4.8% dead (7); 1916, 9.4% (1)
210–250 seedlings per square foot.... 1915, 3.1% dead (3); 1916, 9.2% (2)
Over 250 seedlings per square foot... 1915, ..... dead (0); 1916, 13.7% (3)

On re-averaging the individual plats in two groups, we find:

50–170 seedlings per square foot.... 1915, 8.7% dead (20); 1916, 23.6% (2)
Over 170 seedlings per square foot...1915, 4.3% dead (10); 1916, 11.5% (6)

These counts were made before all of the badly injured seedlings had died. The figures given are the means of the percentages of dead for the individual plats.

The coefficient of correlation between stand density and per cent of seedlings killed for the 1915 plats is $-0.492 \pm 0.093$. While this coefficient is large enough, and the probable error small enough, to indicate that the relation is not likely to be merely accidental, it is to be kept in mind that the correlation does not necessarily indicate a causal relation between the two sets of values. It is entirely possible for example that both the thin stand, and the heavy percentage of loss under snow, frequently observed in the same plat, were due to a third factor: unusual local prevalence of damping-off parasites the preceding summer. The damping-off parasites would have decreased the number of seedlings and at the same time weakened the survivors by causing root sickness, so that the tops would be less resistant to the needle disease during the following winter. There is, however, some reason to believe the relationship between dense stand and slight loss to be a direct one, the dense stands operating to prevent a large portion of the tops of the plants coming into direct contact with the soil during the melting of the snow. There is further indication that keeping the seedlings from direct contact with soil was of value in the results in the spring of 1915 in plats some of which had received a dressing of gravel in the autumn of 1914. The results follow:

Heavy gravel treatment, early count..... 1.6% dead; } Later counts not
Light gravel treatment, early count..... 3.9% dead; } kept separate
Average, gravel plats, early count ..... 2.8% dead; later count 9.0%
Average, control plats, early count ..... 4.0% dead; later count 16.2%

The plats were adjacent, and with approximately the same stand density.

Inspection of the beds indicated that while contact with the tops of other healthy plants is less dangerous than contact with soil, plants in contact with snow-injured plants tend to become diseased, and contact with seedlings killed by damping off, or root rot, the preceding summer is also a predisposing factor. In a plat covered $\frac{1}{4}$ inch deep with sawdust (probably from aspen), an early count showed 15.5 per cent dead, while on the nearest control plats only 6.5 per cent were dead. In the other series in which sawdust was used, the treated plat lost 16 per cent on the early count, and the only available control plat 7.6 per cent. It is suggested that contact with various kinds of dead organic matter, as well as with the soil, predisposes to the disease. This would be expected from the experience reported by other investigators with Botrytis, and recently by Fred[7] with Rhizoctonia, in which weak parasites have been increased in virulence as a result of the presence of abundant substratum for saprophytic growth.

## EXPERIMENTS WITH FUNGICIDES

In the hope of protecting the seedlings during the winter, or at least decreasing the prevalence of the parasites in the beds at the beginning of the winter, the beds were experimentally treated with a number of fungicides in the fall of 1914. In addition to application from a knapsack sprayer, some of the substances were applied in large quantity with a sprinkler in order to secure soil disinfection. So far as could be determined none of the disinfectants materially injure the roots, even in beds of very small four-months-old Douglas fir given heavy sprinklings of sulfuric acid (13 cc. per square foot), commercial lime sulfur solution (44 cc. per square foot), formaldehyde solution (22 cc. commercial formaldehyde per square foot), zinc chlorid (21 gram per square foot), copper sulfate (14 grams per square foot), copper acetate (11 grams per square foot) and ammoniacal copper carbonate (containing 2.6 grams of the carbonate and 26 cc. of strong ammonia per square foot). All of these were applied dissolved in 0.25 to 0.5 liter of water per square foot to a soil already wet. Several of the substances injured the tops of the seedlings. Formaldehyde in 20 volumes of water, applied in quantity equivalent to 22 cc. commercial formaldehyde solution per square foot, quickly resulted in the death of a large number of the seedlings, though the roots seemed still normal the following spring. The same thing happened following the above heavy sprinklings with zinc chlorid (35 pounds per 50 gallons or 84 grams per liter)

[7] Fred, E. B., Relation of green manures to the failure of certain seedlings. Jour. Agr. Research **5**: 1161–1176. 1917.

and ammoniacal copper carbonate ($4\frac{1}{3}$ pounds carbonate and $40\frac{2}{3}$ parts ammonia per 50 gallons or 10.4 grams carbonate and 102 cc. ammonia per liter). Even with weaker solutions of these three, the counts the following spring gave indications of a certain amount of chemical injury to the needle.

In the spraying tests 5–5–50 Bordeaux mixture resulted in a distinctly higher percentage of dead seedlings than in the neighboring control plats, while copper sulfate, 1 pound to 50 gallons (2.4 grams per liter), copper acetate, 1 pound to 50 gallons and 1 pound to 30 gallons (4 grams per liter), and ammoniacal copper carbonate, gave little or no indication of having caused injury. Conifers are considered less liable to chemical injury from the ordinary fungicides than most plants. The rather unexpected injury resulting from the use of the 5–5–50 Bordeaux is probably due to the fact that it stayed on better than the ordinarily more dangerous plain copper salts, and was able to injure the needles during the long period in the latter part of the winter when the seedlings must have been constantly wet from the melting snow.

None of the fungicides mentioned in the foregoing list gave promise of economic value, except possibly lime sulfur solution. Analysis of seedling counts indicated that its use in concentrations of 1 part in 11 or more of water slightly decreased loss. As the season in which the test was made was an abnormal one, in which the plats had remained without permanent snow cover for several weeks after the fungicides were applied, it was hoped that more decisive results could be secured in a more normal season and with more thorough treatment. During the following autumn spraying was started early in the fall by Mr. N. J. Fetherolf and repeated at intervals of two weeks until the beds were permanently snowed in. Five sprayings were made using a knapsack compressed air sprayer and 1 part of commercial lime sulfur solution in 25 to 30 parts of water, with resin-fish-oil soap as an adhesive. The thoroughness with which the work was done was shown by the conspicuous coating of the fungicide still adhering to the plants the following May. A count made early the following spring showed 11.6 per cent of the seedlings dead in the 8 small sample areas in the treated plats, and 13 per cent dead in an equal number of adjacent unsprayed areas. The advantage resulting from this and the preceding year's fungicidal treatments is so slight that there seems to be little hope, at least with Douglas fir of economic control of either snow mould or mulch injury by the application of fungicides.

### SNOW MOULD IN THE FOREST

The writers are advised by Mr. J. M. Fetherolf that Douglas fir has suffered seriously in plantations as well as in nursery beds as a result of mould under snow. Stock planted in the fall, or where there is organic matter on the soil surface, is said to be especially susceptible to such injury. In the spring of 1916, following a winter said to be normal for the locality, one of the writers examined a plantation of Douglas fir made the preceding spring, on the Cache National Forest, in Northern Utah. The examination was made immediately following the disappearance of the snow. Practically all of the dead trees seemed to have died during the preceding season, the roots as well as the tops being dead. As stated earlier in the paper, the roots of snow-moulded plants remain alive for some time after the snow disappears. No definite evidence of snow-mould injury was found. Two years later, examination by Mr. C. F. Korstian confirmed the absence of serious snow-mould injury to planted Douglas fir on the Mink Creek watershed of the Cache Forest. He found, however, in plantations on the Ephraim Canyon watershed of the Manti National Forest that the smaller trees and lower branches of the larger ones were moulded. Douglas fir and Norway and Englemann spruce were the species affected. This he states was mainly limited to areas on which the ground was covered with a deep layer of aspen leaves. He believes that serious loss by mould under snow can be prevented in spring plantings by the use of large vigorous planting stock, which will be less easily covered by the aspen litter. It is considered highly probable, however that in fall planting with Douglas fir the moulding will prove a serious handicap wherever the planting sites remain under snow cover for as much as 6 months.

The relation of mould under snow to the survival of first-year Douglas fir seedlngs in natural reproduction in regions of heavy snow also appears worthy of examination. Dr. Jas. R. Weir in a personal communication describes first-year Douglas fir, cedar, and western white pine seedlings in the heavy snow-fall regions of the Bitter Root Mountains as frequently affected by a prolonged snow cover. A black mycelium which he has found on killed one-year-old Douglas fir after prolonged snow smothering failed to fruit, and he is quite sure that it is not Herpotrichia. *Keithia thujina* he reports[8] as favored in its attacks on *Thuya plicata* by prolonged snow cover.

### CONCLUSIONS

1. Evergreen plants partially smothered by tight packing, or by prolonged mulch or snow cover during the winter, are liable to injury from

[8] Weir, James R., Keithea thujina, the cause of a serious leaf disease of the western red cedar. Phytopathology **6**: 360–363. 1916.

weakly parasitic fungi attacking the leaves. Douglas fir at a high altitude nursery has been especially subject to injury from mould working under the snow, and continuing to work for a time after the snow melts.

2. Plants affected by mulch injury or snow mould can be distinguished from plants killed in certain other ways by the fact that following the mulch or snow injury the roots remain healthy for a considerable time, commonly two or three weeks after the upper parts of the plants are dead.

3. A number of organisms have been obtained in artificial cultures from snow-moulded plants. Of these, *Botrytis cinerea*, and a dark sterile mould so far unidentified, are the ones most strongly suspected of causing the disease. The frequency with which they were found, and their ready growth at 0°C., are the chief reasons for believing them responsible. The Botrytis has furthermore been frequently reported in Europe and America as attacking young growth of Douglas fir, even when no smothering had occurred. Inoculation experiments conducted in a refrigerator gave negative results in most cases because of the amount of disease in the controls. In a series in which the plants were washed with hydrogen peroxide, the controls remained reasonably healthy, and the plants inoculated with the Botrytis and the dark mould were diseased. This experiment should be repeated. It is entirely probable that two or more fungi are able to attack the plants under the conditions prevailing at the surface of the unfrozen soil under the snow drifts.

4. Observation and experiments in the nursery indicate that youth, cutting off of roots, and prolonged smothering, all decrease the resistance of the host, and that contact with the soil or with dead organic matter increases the likelihood of injury. Crowding the seedlings, or surfacing the soil with gravel, probably by keeping the plants from intimate contact with the soil, seems to result in decreasing loss slightly.

5. Spraying and soil-treatment experiments with a number of fungicides applied in the autumn gave no promise of developing any disinfectant or protective treatment of practical value. Commercial lime-sulfur solution gave indications of reducing the amount of injury in two seasons tests, but its effect was very slight. Bordeaux mixture apparently injured the needles during the prolonged soaking under the melting snow. The only procedure which at present promises practical assistance in controlling the snow mould is the practice originating with forest officers of sowing black soil on the snow early in the spring to hasten its melting. Snow moulding can do so much damage and the present prospects of satisfactorily controlling it are so slight, that it is not advisable to establish nurseries for raising Douglas fir on sites which are subjected to prolonged winter snow cover.

6. Moulding under snow sometimes results also in the loss of planted or naturally occurring young trees in the forest, but probably to a less extent than in the nursery beds.

OFFICE OF INVESTIGATIONS IN FOREST PATHOLOGY
BUREAU OF PLANT INDUSTRY.

## BRIEFER ARTICLE

# "CRACK-NECK": A NON-PARASITIC DISEASE OF CHRYSANTHEMUMS

G. H. Chapman

With Plate XXXVII

*Description.* This term is applied to a trouble occurring on fancy forced chrysanthemums raised for exhibition purposes, and to a lesser extent on ordinary potted chrysanthemums not so excessively forced. It is characterized usually by a horizontal rupturing of the stem or "neck" just below the bud or flower head. Occasionally a longitudinal splitting also occurs but this latter condition is rather infrequently found.

The extent of the cracking is variable, sometimes being very slight, at others almost completely girdling the stem or "neck." Often more than one crack may be found on the same stem. Where more are found, one is usually located very close to the bud and the others somewhat lower down on the stem (plate XXXVII) fig. 1, *A* and *B*).

The rupture is often comparatively deep, sometimes extending through all the outer tissues and into the pith. Plate XXXVII, figs. 4 and 5, show a longisection through the ruptured stem, and a cross section of the same stem just below the rupture. It will be noted that in this case the rupture extends through the outer tissues and trachea, but not deep enough to cut all.

*Occurrence and extent of injury.* This trouble was first noted in the greenhouses of the Massachusetts Agricultural College in October of 1917, and was subsequently observed elsewhere. In 1918, it was again noted in some greenhouses. The injury occurred in all cases just as the plant was ready to bloom. An examination of the plants in the beds showed many which had one or more lesions, the number of plants affected being rather unequally distributed between the different varieties. Those most seriously affected were the Mountain Greenwood, the Yellow Turner, and the White Turner, the first showing about 80 per cent of the plants injured, the last not over 50 per cent. Other varieties showed little or no injury. An interesting feature also noted was that only plants which had been crown budded showed any injury, terminal budded plants in no case showing any signs of lesions, even on those varieties which were apparently the most susceptible.

*Cause.* It was plainly evident that no organism was connected with the trouble and it appeared to be due to a sudden displacement of the equilibrium normally existing between the temperature and moisture relations and root pressure, so-called. Investigation of the fertilization indicated that an excess of plant food could not be a contributory cause, and the condition of the plants did not indicate the presence of continued excessive soil moisture. All the plants presented a healthy, robust appearance. It was evident that overfeeding and continued excessive watering should be eliminated from consideration.

There are, however, in addition to strictly oedemic conditions, other types of non-parasitic disorders which have been noted by Sorauer[1] and others, in which a rupture of the roots, stems or fruit occurs, due in some cases to a *sudden* excess of water supply, and in others to a rapid lowering of the air temperature accompanied by rain and a consequent high humidity. These latter conditions, as has been repeatedly shown by investigators, result in a very much decreased transpiration. The above-mentioned disorders have been reported not only on vegetables, fruits and herbaceous plants, but on trees, to a lesser degree, as well.

It was believed that a similar set of factors might be responsible for the injury observed on the chrysanthemum, and a careful study of the conditions existing in the house prior to the time the injury was first noted yielded interesting data.

Up to September 29 no injury had been observed on any of the plants. The thirtieth was a dull, overcast day, but the temperature of the house was normal for the plants at that stage of maturity (58°–62° F.). The beds were watered rather late in the afternoon, about 4.00 p.m. A violent rain storm occurred still later in the afternoon, and the air temperature dropped several degrees very rapidly. The house also cooled rapidly. No heat was available during the night and the temperature in the house remained very low, 42° to 44°. The humidity remained rather high during the night. On the other hand the temperature of the soil in the beds did not drop greatly, so far as could be ascertained. It is a well-known fact, however, that the soil responds to changes in air temperature rather slowly, especially when well supplied with water, as was the case here. The following day was also cool and overcast. The next morning several of the plants developed the characteristic cracking.

There existed then the following situation preceding the injury: (1) very little transpiration taking place as a result of the low air temperature and the high humidity, and (2) the soil temperature remaining practically stationary, the soil having been previously well supplied with mois-

[1] Sorauer, Paul. Handbuch der Pflanzenkrankheiten, Band I, pp. 321 and 461.

ture, and the roots functioning normally in so far as the absorption of water and solutes was concerned.

These and similar conditions always bring about abnormal cell relations and, in consequence, an excessive turgor is brought about in some of the cells with no normal means of regulation, such as occurs when the plants are transpiring freely, and as a result some of the tissues must give way to permit of a return to the normal condition.

That the conditions above mentioned are capable of producing a cracking of the necks of chrysanthemums has been shown experimentally by duplicating the conditions in the greenhouse, also by cutting the stems, attaching a tight rubber connection to the cut end, and subjecting the tissues to water pressure. The cracking and splitting produced experimentally are shown in plate XXXVII, figures 2 and 3.

*Control measures.* It was suggested as a probable means of control that the night temperatures be raised as much as possible, consistent with the best development of the plants, and that during dull weather water be withheld as much as possible, or, in any case, be applied in the morning. These directions were followed, and although considerable cool, cloudy weather followed no further trouble was experienced.

Later many of the lesions calloused over and the blossoms developed, but in every case there was some distortion or unequal development of the blooms, rendering them unsuitable for exhibition or sale.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION
AMHERST, MASSACHUSETTS.

PLATE XXXVII

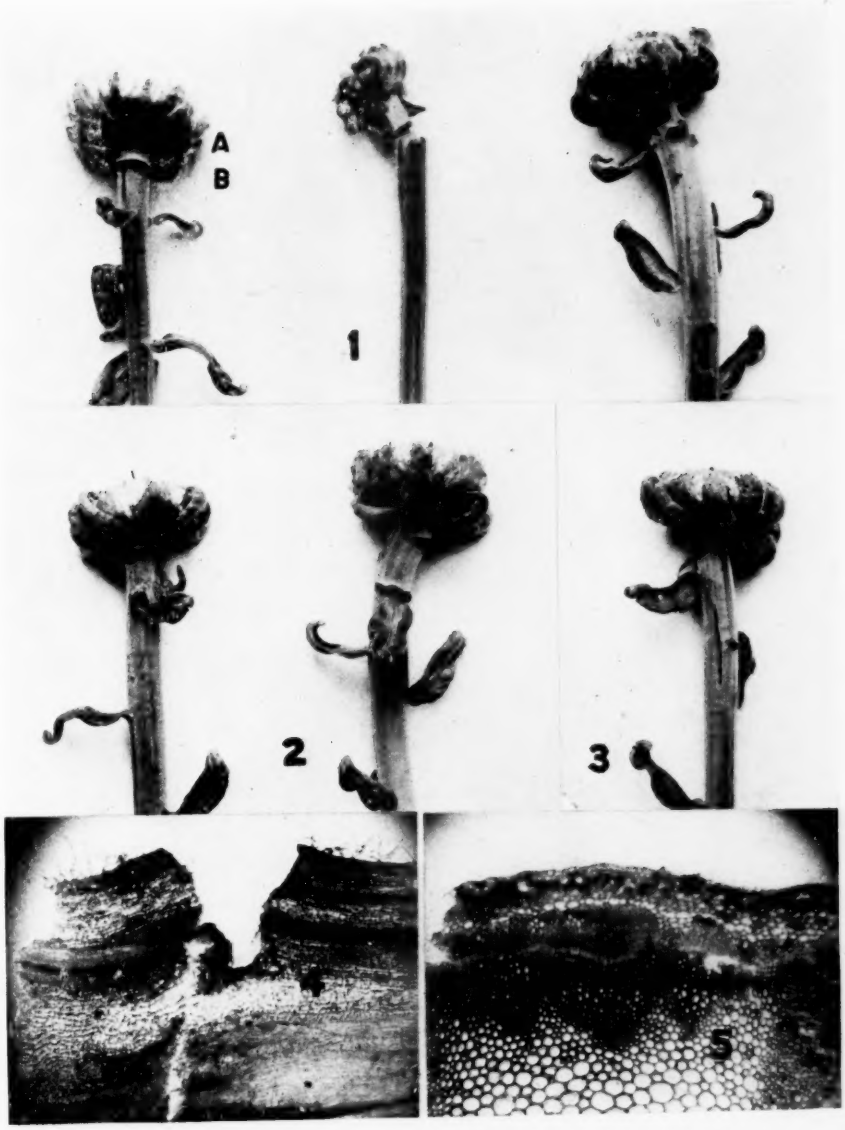
FIG. 1. Chrysanthemums showing natural cracking and splitting of the "neck." *A* and *B*, a double cracking on one "neck."

FIG. 2. Cross cracking experimentally produced.

FIG. 3. Longi-splitting experimentally produced.

FIG. 4. Longisection through a ruptured "neck."

FIG. 5. Cross section of stem just below the rupture.




CHAPMAN: "CRACK-NECK" DISEASE OF CHRYSANTHEMUMS

## PHYTOPATHOLOGICAL NOTES

Dr. Lex R. Hesler, formerly Assistant Professor of Plant Pathology in the Cornell College of Agriculture, has been appointed Professor of Botany and head of the Department of Botany in the College of Agriculture, University of Tennessee, Knoxville, Tennessee.

Dr. W. D. Valleau, formerly of the University of Minnesota, has just returned from overseas service in France and Germany and has accepted the position of plant pathologist at the University of Kentucky.

Mr. H. W. Thurston, of the University of Nebraska, will work on rust epidemiology studies in the Southwest for the Office of Cereal Investigations.

Mr. A. G. Newhall, recently a graduate student at the University of Minnesota, has been appointed instructor in plant pathology and bacteriology at Grinnell College, Grinnell, Iowa.

Mr. A. G. Tolaas, former Extension Plant Pathologist at the University of Minnesota, is now in charge of the Potato Seed Certification work in Minnesota. Mr. Frank Frolik, who has been engaged in barberry and black rust investigations for the Office of Cereal Investigations, has been elected Extension Plant Pathologist to succeed Mr. Tolaas.

# APPENDIX

## THE LONG ISLAND POTATO DISEASE CONFERENCE

There was held on Long Island, New York, June 24 to June 28, a notable conference of plant pathologists to which were also invited investigators and teachers interested in the potato crop from the standpoint of botany, entomology, agronomy, soils and genetics.

The purposes of this conference, which was organized by the Advisory Board of American Plant Pathologists were (1) to bring together in a field meeting as many pathologists as possible for the purpose of discussing in particular the mosaic, leaf roll and degeneration diseases of the potato; (2) to establish closer relationships between those persons representing different phases of the industry and science of growing and protecting this particular crop; (3) to bring together in closer bondage the plant pathologists of different nations; (4) to promote further coöperative effort toward the solution of the problems concerned.

Two days were devoted to visiting the field experiments conducted by representatives of the New York State College of Agriculture, the Geneva Agricultura lExperiment Station, the Canadian Department of Agriculture, the United States Department of Agriculture and the Bermuda Department of Agriculture on the Eastern end of Long Island. The success of the conference was largely due to the efforts of the Suffolk County Farm Bureau Agent, Mr. R. C. Parker, to Prof. H. H. Whetzel, who personally conducted the tour and to Dr. M. F. Barrus, who arranged the program.

Among the field tests of especial interest were a fertilizer test showing the influence of the presence or absence of potash, with or without an unbalanced fertilizer, in promoting the development of the condition known as "potash hunger;" potato mosaic experiments designed to show the effect of selecting apparently healthy seed from fields containing different percentages of mosaic the previous year and also to determine to what degree mosaic shows on Long Island compared with Northern New York from identical seed; experiments to show the influence of climate upon degeneration of potatoes; and the comparison between mature and immature seed from the same source planted at the same time. Further plantings to demonstrate the importance of seed source, and the symptoms of leaf-roll and mosaic, were also inspected with interest.

Two maladies, unfamiliar to most of those in attendance, were observed. One of these was called to the attention of the visitors by Dr. H. M. Quanjer and occurred generally on the plot in the fertilizer test which had received an application of calcium cyanamid. Dr. Quanjer pronounced the trouble "pseudomosaic" and stated that it had been observed in Holland where calcium cyanamid had been applied alone previous to planting potatoes. The malady manifests itself by a crinkling of foliage, a general paling of the plants and a characteristic whitening of the margins of leaflets. The other disease was characterized by a pronounced yellowing and dwarfing of the plants with an upward rolling of the leaflets accompanied by a decided internal browning of the tubers, which were about normal in number but small in size.

Of the representatives invited from the botanic, entomologic, agronomic, genetic and soils sciences some were present from each. There were in all about one hundred in attendance. Their interest was much aroused in plant pathological subjects and they expressed a keen appreciation of the value of such conferences.

Most notable of the results achieved by the conference was the presence of five representatives from foreign countries. Dr. A. D. Cotton, Mycologist of the Board of Agriculture, England; Dr. George H. Pethybridge, Pathologist of the Board of Agriculture, Ireland; Dr. H. M. Quanjer of the Pathological Laboratory at Wageningen, Holland; Mr. E. J. Wortley, Director of Agriculture, Bermuda; and Mr. P. A. Murphy, Pathologist of the Dominion of Canada, St. Catharines, Ontario, were present and contributed much to the success and interest of the conference. Dr. Cotton spoke upon the developments along phytopathological lines in England, Dr. Pethybridge gave a history of plant pathology in Ireland and the organization of the work there, and Dr. Quanjer presented in a most interesting paper, the results of his researches upon the nature of leaf-roll. It is confidently expected that this first international meeting of plant pathologists presages for the future regular international meetings and the establishment of permanent relationships in our science, which is far too broad in its aspects to remain only national in scope.

In a coöperative way the Long Island Conference was a pronounced success. It demonstrated beyond question the feasibility of coöperative effort in the conduct of field experimentation for the solution of many problems which require a study of the effects of different environments on specific problems. The possibilities in coöperative efforts were enthusiastically discussed and approved not only by American but also by the visiting European representatives at the conference.

The third day of the conference was devoted to some brief visits in the market gardening region in Nassau County and some points of general interest including a visit to Sagamore Hill and the late Ex-President Roosevelt's grave. The evenings were devoted to general discussions and the presentation of papers including an important one on the "Spindling Sprout Disease of Potatoes" presented by Dr. C. O. Appleman of Maryland Agricultural College.

On Saturday, June 28, the pathologists in the Northeast District met at the Brooklyn Botanic Garden for a conference and were again addressed by Dr. H. M. Quanjer who gave an illustrated lecture on the subject of "Leaf-roll" and "Mosaic" of potatoes. This was followed by brief discussion on some apple and tomato diseases.

The Advisory Board desires to thank the farmers and County Agents of Suffolk and Nassau Counties, Dr. Gager and others of the Brooklyn Botanic Garden and especially Dr. M. F. Barrus, Chairman of the Committee on Arrangements, for their generous assistance in making the meetings such a success.

C. R. ORTON,
*Secretary Advisory Board of American Plant Pathologists.*

# LITERATURE ON PLANT DISEASES[1]

COMPILED BY ALICE C. ATWOOD AND FLORENCE P SMITH, BIBLIOGRAPHICAL ASSISTANTS, BUREAU OF PLANT INDUSTRY

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[1] This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7, no. 3, June, 1917.

All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agric., Washington, D. C.

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